Table 5.3-1. Wolman Samples Collected between Thermalito Diversion Dam and Honcut Creek in 2002-2003.

River Mile (USACE)	Riffle/Feature	Office Code	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
* "Office Code" is defined sequentially by the following: 1) Type of sample --- BS = bulk sample, WS = Wolman sample; 2) Feature --- r = riffle, b = bar, g = glide, t = tailings, blank = unspecified; 3) Location --- t = top (upstream) end of feature, m = middle of feature, b = bottom (downstream) end of feature, blank = unspecified; 4) Number --- consecutive numbering consistent in 1982, 1996, 2002/2003;								5) Local feature --- d = dune, t = trough, e = embedded, blank = unspecified; 6) Year--- year that this site was last sampled --- main years of sampling are 1982, 1996 and 2002/2003, xx means this is the first year sampled; 7) Year--- year that this sample was taken; 8) Vertical stratum sampled --- A = surface, B = subsurface, C = both							
River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis ---Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
* "Office Code" is defined sequentially by the following: 1) Type of sample --- BS = bulk sample, WS = Wolman sample; 2) Feature --- r = riffle, b = bar, g = glide, t = tailings, blank = unspecified; 3) Location --- t = top (upstream) end of feature, m =	5) Local feature --- d = dune, t = trough, e = embedded, blank = unspecified; 6) Year--- year that this site was last sampled --- main years of sampling are 1982, 1996 and 2002/2003, xx means this is the first year sampled; 7) Year--- year that this sample was taken; 8) Vertical stratum sampled --- A = surface, B = subsurface, C = both														

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River Mile (USACE)	Riffle/Feature	Office Code	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
middle of feature, b = bottom (downstream) end of feature, blank = unspecified; 4) Number --- consecutive numbering consistent in 1982, 1996, 2002/2003;															
71.500	OROVILLE DAM														
67.128	THERMALITO DIVERSION DAM														
66.541	FISH BARRIER DAM														
66.097	Hatchery Riffle	WS-bt102-82-2002A	32	61	76	133	192	223	256	116	1.91	80.97	skewed towards coarse	normal	moderate
66.087	Hatchery Riffle	WS-rt102-96-2002A	30	67	85	141	198	226	256	123	1.84	79.59	very skewed towards coarse	normal	moderate
65.869	Moe's Ditch	WS-bm004-82-2003A	11	25	36	59	103	124	176	55	2.25	49.79	skewed towards coarse	normal	poor
65.764	Auditorium Riffle	WS-bb001A-82-2002A	1	3	6	15	29	32	64	10	3.19	14.30	very skewed towards coarse	normal	poor
65.762	Auditorium Riffle	WS-bb001B-82-2002A	4	10	18	37	70	87	120	29	2.94	38.40	skewed towards coarse	normal	poor
65.757	Auditorium Riffle	WS-rt002-96-2002A	1	9	21	40	87	120	168	33	3.62	55.42	very skewed towards	highly peaked	very poor

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River Mile (USACE)	Riffle/Feature	Office Code	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
													coarse		
65.234	Bedrock Park Riffle	WS-gm004-82-2002A	25	48	70	124	174	206	288	99	2.07	79.18	very skewed towards coarse	normal	poor
65.143	Bedrock Park Riffle	WS-bb003-82-2002A	1	15	22	41	71	86	125	37	2.37	35.51	very skewed towards coarse	very highly peaked	poor
65.002	HIGHWAY 70 BRIDGE														
63.872	HIGHWAY 162 BRIDGE														
63.476	Mathews Riffle	WS-rt020-82-2002A	20	39	56	93	139	162	208	79	2.04	61.44	skewed towards coarse	normal	poor
62.887	Aleck Riffle	WS-BS-rt005-96-2003A	29	55	77	127	217	243	319	115	2.11	93.96	skewed towards coarse	normal	poor
62.781	Aleck Riffle	WS-rm172-82-2003A	19	32	49	82	150	182	241	76	2.39	75.12	skewed towards coarse	normal	poor
62.636	Aleck Tailings	WS-TP-bm009-xx-2003A	18	38	51	90	147	169	223	80	2.12	65.65	skewed towards coarse	normal	poor
61.381	Robinson Riffle (upper)	WS-BS-rt006-xx-2003A	21	44	59	96	123	138	174	78	1.78	47.25	very skewed towards coarse	highly peaked	moderate
61.144	Robinson Riffle (lower)	WS-BS-bt007-96-2003A	15	32	47	102	153	174	231	74	2.34	70.93	very skewed towards coarse	normal	poor
61.007	Robinson Riffle (lower)	WS-rb175-82-2003A	3	14	25	50	78	87	127	35	2.49	36.58	very skewed towards coarse	highly peaked	poor
60.916	Robinson (lower)/Steep	WS-bt108-82-2003A	14	23	30	52	90	117	187	51	2.27	46.97	symmetrical	normal	poor

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River Mile (USACE)	Riffle/Feature	Office Code	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
60.874	Robinson (lower)/Steep	WS-bm109-82-2003A	8	17	23	50	84	106	159	42	2.51	44.69	skewed towards coarse	normal	poor
60.821	Robinson (lower)/Steep	WS-bm110-82-2003A	7	15	22	38	67	82	137	35	2.36	33.83	skewed towards coarse	normal	poor
60.758	Robinson (lower)/Steep	WS-bb111-82-2003A	1	2	10	39	77	105	156	13	7.75	51.38	very skewed towards coarse	normal	very poor
60.710	Steep Riffle	WS-bb107a-82-2003A	1	1	1	17	37	44	64	7	6.76	21.74	very skewed towards coarse	very flat	very poor
60.708	Steep Riffle	WS-rt107-96-2003A	1	1	9	30	61	83	138	9	9.21	40.98	very skewed towards coarse	normal	very poor
60.690	Steep Riffle	WS-bb107b-82-2003A								0	#DIV/0!	0.00			
60.636	Steep Riffle	WS-rm106-82-2003A	9	21	27	44	69	81	116	41	1.98	30.24	skewed towards coarse	highly peaked	poor
60.607	Steep/Weir	WS-bt104-82-2003A	8	18	26	53	111	142	209	51	2.79	61.79	skewed towards coarse	normal	poor
60.545	Steep/Weir	WS-bm005-82-2003A	15	38	66	114	159	177	235	82	2.17	69.75	very skewed towards coarse	highly peaked	poor
60.510	Weir Riffle	WS-gt008-82-2003A	15	40	53	89	124	147	179	77	1.91	53.35	very skewed towards coarse	highly peaked	poor
60.493	Weir Riffle	WS-BS-bb009-82-2003A	7	21	33	63	107	125	173	52	2.42	51.68	very skewed towards coarse	normal	poor
60.447	Weir Riffle	WS-gm006-82-2003A	12	23	34	57	89	113	164	52	2.20	44.94	skewed towards coarse	highly peaked	poor

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River Mile (USACE)	Riffle/Feature	Office Code	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
59.977	Eye Riffle	WS-BS-rt021-96-2003A	8	23	31	57	107	125	170	53	2.34	51.03	skewed towards coarse	normal	poor
59.489	Gateway Riffle	WS-rt112-96-2003A	35	51	62	90	149	169	228	93	1.82	59.06	symmetrical	flat	moderate
58.722	THERMALITO SPILLWAY														
58.405	Sutter Butte Riffle	WS-rt119-82-2003A	4	19	33	58	91	112	151	47	2.41	46.50	very skewed towards coarse	highly peaked	poor
58.389	Sutter Butte Riffle	WS-rt017-82-2003A	10	19	29	60	92	117	159	47	2.47	48.98	skewed towards coarse	normal	poor
57.161	Conveyor Belt Riffle	WS-rt123-xx-2003A	17	31	43	76	110	127	174	62	2.03	48.12	skewed towards coarse	normal	poor
56.323	Hour Riffle (upper)	WS-rb034-82-2003A	5	22	34	54	80	90	117	44	2.05	34.48	very skewed towards coarse	very highly peaked	poor
56.323	Hour Riffle (upper)	WS-BS-rb013-xx-2003A	10	26	36	64	118	137	172	60	2.28	55.34	skewed towards coarse	normal	poor
54.652	Keister Riffle	WS-BS-bt014-96-2003A	21	35	42	64	88	105	143	61	1.74	35.31	skewed towards coarse	normal	moderate
54.630	Keister Riffle	WS-bt137/138-82-2003A	20	36	43	62	89	109	144	62	1.74	36.31	skewed towards coarse	normal	moderate
54.474	Goose Riffle	WS-BS-bb015-96-2003A	11	22	28	47	73	87	122	44	1.97	32.24	skewed towards coarse	normal	poor
53.886	Goose Backwater Tailings	WS-TP-bm004-xx-2003A	12	25	34	63	89	109	148	52	2.10	42.29	skewed towards coarse	normal	poor
53.627	Big Riffle	WS-BS-rt017-96-2003A	8	22	34	70	107	120	156	51	2.33	48.85	very skewed towards	normal	poor

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River Mile (USACE)	Riffle/Feature	Office Code	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
													coarse		
53.580	Big Riffle	WS-bt043a-82-2003A	10	36	51	86	126	149	175	73	2.04	56.45	very skewed towards coarse	highly peaked	poor
53.576	Big Riffle	WS-bt143-82-2003A	8	22	38	72	114	136	171	54	2.49	56.85	very skewed towards coarse	highly peaked	poor
52.305	MacFarland Riffle (upper)	WS-BS-bt018-xx-2003A	20	32	42	64	87	102	126	57	1.79	34.93	skewed towards coarse	normal	moderate
52.056	MacFarland Riffle (upper)	WS-bt149-82-2003A	1	9	19	47	71	83	113	28	2.97	36.91	very skewed towards coarse	highly peaked	poor
50.545	GRIDLEY HIGHWAY BRIDGE														
48.685	Junkyard Riffle (upper)	WS-BS-rt020-xx-2003A	8	14	18	32	49	59	80	29	2.02	22.26	skewed towards coarse	normal	poor
48.666	Junkyard Riffle (upper)	WS-bt057-82-2003A	13	22	28	43	60	71	95	40	1.79	24.55	skewed towards coarse	normal	moderate
46.462	Herringer Riffle (lower)	WS-BS-bb023-xx-2003A	6	16	22	37	56	62	80	31	1.96	22.81	very skewed towards coarse	highly peaked	poor
46.239	Herringer Riffle (lower)	WS-bt068-xx-2003A	1	11	22	41	61	73	91	29	2.54	30.75	very skewed towards coarse	very highly peaked	poor

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Table 5.3-2. Wolman Samples Collected between Thermalito Diversion Dam and Honcut Creek in 1996.

River Mile (USACE)	Riffle/Feature	Office Code*	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
* "Office Code" is defined sequentially by the following: 1) Type of sample --- BS = bulk sample, WS = Wolman sample; 2) Feature --- r = riffle, b = bar, g = glide, t = tailings, blank = unspecified; 3) Location --- t = top (upstream) end of feature, m = middle of feature, b = bottom (downstream) end of feature, blank = unspecified; 4) Number --- consecutive numbering consistent in 1982, 1996, 2002/2003;							5) Local feature --- d = dune, t = trough, e = embedded, blank = unspecified; 6) Year--- year that this site was last sampled --- main years of sampling are 1982, 1996 and 2002/2003, xx means this is the first year sampled; 7) Year--- year that this sample was taken; 8) Vertical stratum sampled --- A = surface, B = subsurface, C = both							
71.500	OROVILLE DAM														
67.128	THERMALITO DIVERSION DAM														
66.541	FISH BARRIER DAM														
66.283	TABLE MOUNTAIN BRIDGE														
66.034	Hatchery Riffle	WS-rt102-82-1996A	48	61	97	122	219	237	364	120	1.97	88.08	symmetrical	normal	moderate
65.764	Moe's Ditch	WS-rt002-82-1996A	15	29	46	57	63	97	119	53	1.83	34.07	skewed towards coarse	very highly peaked	moderate
65.295	Bedrock Park Riffle	WS-bm103-82-1996A	31	32	32	51	59	61	64	44	1.39	14.85	very skewed towards coarse	very flat	well
65.002	HIGHWAY 70 BRIDGE														
63.872	HIGHWAY 162 BRIDGE														
63.467	Mathews Riffle	WS-rt021-82-1996A	16	51	61	111	125	191	237	99	1.93	69.73	very skewed towards coarse	very highly peaked	poor
62.862	Aleck Riffle	WS-BS-bt005-xx-1996A	32	49	55	91	119	127	250	79	1.61	39.17	skewed towards coarse	normal	moderate
62.181	Great Western Riffle	WS-BS-bt006-xx-	16	25	28	47	59	62	114	40	1.57	18.46	skewed	normal	moderate

River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
		1996A											towards coarse		
61.111	Robinson Riffle (lower)	WS-BS-bm007-xx-1996A	55	63	97	114	124	127	232	89	1.42	32.11	very skewed towards coarse	very highly peaked	moderately well
60.706	Steep Riffle	WS-rt107-82-1996A	8	13	15	27	31	32	91	21	1.54	9.19	very skewed towards coarse	highly peaked	moderate
60.458	Weir Riffle	WS-bb006-82-1996A	27	30	31	52	61	64	118	44	1.46	16.96	skewed towards coarse	flat	moderately well
59.973	Eye Riffle	WS-BS-rm021-xx-1996A	32	55	59	99	118	123	194	82	1.50	34.08	very skewed towards coarse	normal	moderately well
59.500	Gateway Riffle	WS-rt112-82-1996A	32	48	52	59	63	99	121	69	1.44	25.71	skewed towards fine	very highly peaked	moderately well
58.722	THERMALITO SPILLWAY														
58.396	Sutter Butte Riffle	WS-rt119/017-82-1996A	16	24	27	31	56	60	97	38	1.57	17.84	very skewed towards fine	normal	moderate
56.329	Hour Riffle (upper)	WS-BS-bm034-xx-1996A	29	51	55	62	107	116	125	77	1.51	32.49	skewed towards fine	flat	moderately well
54.668	Keister Riffle	WS-BS-rt014-xx-1996A	32	47	53	63	110	118	126	74	1.58	35.44	skewed towards fine	flat	moderately well
54.449	Keister/Big	WS-BS-bb015-xx-1996A	24	30	32	56	63	98	120	54	1.82	34.07	symmetrical	normal	moderate
53.645	Big Riffle	WS-BS-bt017-xx-1996A	16	25	28	46	57	60	64	39	1.54	17.45	very skewed towards coarse	flat	moderately well
52.063	MacFarland Riffle (upper)	WS-bm149-82-1996A	16	27	29	47	57	60	63	40	1.50	16.82	very skewed towards coarse	flat	moderately well
50.545	GRIDLEY HIGHWAY BRIDGE														
49.398	Gridley Riffle	WS-rt051-82-1996A	16	16	25	29	32	50	60	28	1.76	16.76	symmetrical	very highly peaked	moderately well
48.659	Junkyard Riffle (upper)	WS-bt057-82-1996A	15	26	28	31	51	56	62	38	1.48	15.27	skewed towards fine	normal	moderately well

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River Mile (USACE)	Riffle/Feature	Office Code*	D5 (mm)	D16 (mm)	D25 (mm)	D50 (mm)	D75 (mm)	D84 (mm)	D95 (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
44.315	HONCUT CREEK														

Table 5.3-3. Wolman Samples Collected between Thermalito Diversion Dam and Honcut Creek in 1982.

River Mile (USACE)	Riffle/Feature	Office Code*	D5 (mm)	D16 (mm)	D25 (mm)	D50 (mm)	D75 (mm)	D84 (mm)	D95 (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
* "Office Code" is defined sequentially by the following: 1) Type of sample --- BS = bulk sample, WS = Wolman sample; 2) Feature --- r = riffle, b = bar, g = glide, t = tailings, blank = unspecified; 3) Location --- t = top (upstream) end of feature, m = middle of feature, b = bottom (downstream) end of feature, blank = unspecified; 4) Number --- consecutive numbering consistent in 1982, 1996, 2002/2003;							5) Local feature --- d = dune, t = trough, e = embedded, blank = unspecified; 6) Year--- year that this site was last sampled --- main years of sampling are 1982, 1996 and 2002/2003, xx means this is the first year sampled; 7) Year--- year that this sample was taken; 8) Vertical stratum sampled --- A = surface, B = subsurface, C = both							
71.50	OROVILLE DAM														
67.13	THERMALITO DIVERSION DAM														
66.54	FISH BARRIER DAM														
66.28	TABLE MOUNTAIN BRIDGE														
66.09	Hatchery Riffle	WS-bb101-xx-1982A	2	31	---	69	---	115	150	60	1.93	42.00	very skewed to coarse	----	poor
66.05	Hatchery Riffle	WS-bt102-xx-1982A	10	35	---	90	---	170	255	77	2.20	67.50	very skewed to coarse	----	poor
65.78	Auditorium Riffle	WS-rt002-xx-1982A	4	16	---	51	---	74	90	34	2.15	29.00	very skewed to coarse	----	poor
65.77	Auditorium Riffle	WS-bb001-xx-1982A	5	10	---	29	---	53	72	23	2.33	21.60	very skewed to coarse	----	poor
65.30	Bedrock Park Riffle	WS-gt103-xx-1982A	5	27	---	110	---	190	255	72	2.65	81.50	symmetrical	----	poor
65.23	Bedrock Park Riffle	WS-gm004-xx-1982A	4	16	---	61	---	143	190	47	3.04	63.75	very skewed to coarse	----	poor

River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	D_g (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
65.14	Bedrock Park Pool	WS-bb003-xx-1982A	5	15	---	39	---	128	180	44	2.92	56.50	skewed to coarse	----	poor
65.00	HIGHWAY 70 BRIDGE														
63.87	HIGHWAY 162 BRIDGE														
63.58	Mathews Riffle	WS-rt121-xx-1982A	6	19	---	46	---	76	100	38	2.00	28.50	very skewed to coarse	----	poor
63.57	Mathews Riffle	WS-rt122-xx-1982A	4	14	---	43	---	80	105	33	2.43	33.00	very skewed to coarse	----	poor
63.48	Mathews Riffle	WS-rt019-xx-1982A	4	20	---	63	---	120	170	49	2.45	50.00	very skewed to coarse	----	poor
63.47	Mathews Riffle	WS-rt020-xx-1982A	12	23	---	69	---	106	150	49	2.17	41.75	very skewed to coarse	----	poor
63.46	Mathews Riffle	WS-rt021-xx-1982A	3	8	---	44	---	81	110	25	3.18	36.50	very skewed to coarse	----	poor
62.78	Aleck Riffle	WS-rm172-xx-1982A	4	14	---	42	---	72	98	32	2.27	29.00	skewed to coarse	----	poor
62.76	Aleck Riffle	WS-rm072-xx-1982A	10	17	---	58	---	96	125	40	2.38	39.50	very skewed to coarse	----	moderate
61.96	Great Western Riffle	WS-rb173-xx-1982A	12	33	---	80	---	170	260	75	2.27	68.50	very skewed to coarse	----	poor
61.94	Great Western Riffle	WS-rb174-xx-1982A	19	31	---	69	---	105	140	57	1.83	36.80	skewed to coarse	----	moderate
61.60	Great Western Riffle	WS-bb073-xx-1982A	9	17	---	58	---	100	135	41	2.43	41.50	very skewed to coarse	----	poor
61.25	Robinson Riffle (upper)	WS-rt074-xx-1982A	24	45	---	94	---	150	195	82	1.83	52.50	skewed to coarse	----	poor
61.01	Robinson Riffle (lower)	WS-bb175-xx-1982A	4	20	---	56	---	90	115	42	2.12	35.00	skewed to coarse	----	poor
60.92	Robinson (lower)/Steep	WS-bt108-xx-1982A	11	22	---	60	---	130	160	53	2.43	54.00	very skewed to coarse	----	poor
60.87	Robinson (lower)/Steep	WS-bm109-xx-1982A	11	28	---	66	---	135	165	61	2.20	53.50	skewed to coarse	----	poor
60.82	Robinson (lower)/Steep	WS-bm110-xx-1982A	7	19	---	60	---	110	150	46	2.41	45.50	very skewed to coarse	----	poor

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River Mile (USACE)	Riffle/Feature	Office Code*	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
60.76	Robinson (lower)/Steep	WS-bb111-xx-1982A	5	11	---	28	---	56	74	24	2.31	22.75	very skewed to coarse	----	poor
60.70	Steep Riffle	WS-rt107-xx-1982A	9	29	---	72	---	110	145	56	1.95	40.50	very skewed to coarse	----	poor
60.64	Steep Riffle	WS-bt106-xx-1982A	11	39	---	102	---	164	200	80	2.05	62.50	very skewed to coarse	----	poor
60.61	Steep Riffle	WS-bm104-xx-1982A	11	30	---	84	---	145	175	66	2.20	57.50	skewed to coarse	----	poor
60.60	Steep Riffle	WS-rb105-xx-1982A	3	8	---	32	---	66	93	23	2.87	29.00	skewed to coarse	----	moderate
60.54	Steep/Weir	WS-bm005-xx-1982A	10	23	---	52	---	108	170	50	2.17	42.50	skewed to coarse	----	moderate
60.50	Weir Riffle	WS-rt008-xx-1982A	12	27	---	58	---	95	130	51	1.88	34.00	symmetrical	----	poor
60.48	Weir Riffle	WS-rt007-xx-1982A	22	44	---	80	---	133	165	76	1.74	44.50	skewed to coarse	----	poor
60.45	Weir Riffle	WS-rm006-xx-1982A	12	21	---	45	---	138	170	53	2.59	58.75	skewed to coarse	----	poor
60.35	Weir Riffle	WS-rb009-xx-1982A	5	16	---	48	---	130	160	46	2.85	57.00	skewed to coarse	----	poor
60.07	Eye Riffle	WS-rt176-xx-1982A	8	21	---	56	---	113	150	49	2.32	46.00	very skewed to coarse	----	poor
59.49	Gateway Riffle	WS-rm112-xx-1982A	6	12	---	38	---	75	110	29	2.55	31.75	skewed to coarse	----	poor
59.47	Gateway Riffle	WS-rm113-xx-1982A	9	16	---	40	---	66	82	32	2.06	25.25	skewed to coarse	----	moderate
59.45	Gateway Riffle	WS-rm010-xx-1982A	10	20	---	45	---	80	105	39	2.03	30.25	skewed to coarse	----	moderate
59.12	Gateway/Thermalito	WS-bm014-xx-1982A	14	25	---	52	---	88	120	47	1.88	31.50	skewed to coarse	----	poor
59.08	Gateway/Thermalito	WS-bm015-xx-1982A	17	29	---	60	---	94	120	52	1.80	32.50	very skewed to coarse	----	poor
59.02	Gateway/Thermalito	WS-rm116-xx-1982A	6	12	---	32	---	55	74	25	2.17	21.65	very skewed to coarse	----	poor
59.01	Gateway/Thermalito	WS-rm117-xx-1982A	7	12	---	28	---	51	70	25	2.07	19.55	very skewed to coarse	----	moderate

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River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
58.85	Gateway/Thermalito	WS-bt114-xx-1982A	3	8	---	47	---	88	115	27	3.28	39.90	skewed to coarse	----	moderate
58.77	Gateway/Thermalito	WS-bm115-xx-1982A	12	45	---	78	---	117	150	73	1.61	36.00	skewed to coarse	----	poor
58.72	THERMALITO SPILLWAY														
58.70	Thermalito/Sutter Butte	WS-bb011-xx-1982A	37	59	---	107	---	160	200	97	1.65	50.50	skewed to coarse	----	poor
58.68	Thermalito/Sutter Butte	WS-bb012-xx-1982A	12	31	---	67	---	131	160	64	2.06	50.00	very skewed to coarse	----	poor
58.66	Thermalito/Sutter Butte	WS-bb013-xx-1982A	13	25	---	76	---	130	160	57	2.28	52.50	skewed to coarse	----	poor
58.48	Sutter Butte Riffle	WS-rt118-xx-1982A	3	10	---	25	---	55	100	23	2.35	22.50	very skewed to coarse	----	poor
58.47	Sutter Butte Riffle	WS-rt016-xx-1982A	10	21	---	56	---	84	105	42	2.00	31.50	symmetrical	----	poor
58.41	Sutter Butte Riffle	WS-rm127-xx-1982A	7	20	---	53	---	100	150	45	2.24	40.00	skewed to coarse	----	moderate
58.40	Sutter Butte Riffle	WS-rm124-xx-1982A	9	19	---	57	---	88	110	41	2.15	34.50	skewed to coarse	----	poor
58.40	Sutter Butte Riffle	WS-rm119-xx-1982A	5	11	---	32	---	96	135	33	2.93	42.40	skewed to coarse	----	moderate
58.40	Sutter Butte Riffle	WS-rm024-xx-1982A	20	38	---	70	---	110	160	64	1.71	36.25	very skewed to coarse	----	poor
58.40	Sutter Butte Riffle	WS-rm023-xx-1982A	9	16	---	43	---	90	130	37	2.41	37.25	skewed to coarse	----	poor
58.39	Sutter Butte Riffle	WS-rm125-xx-1982A	12	25	---	52	---	86	115	46	1.86	30.55	very skewed to coarse	----	poor
58.39	Sutter Butte Riffle	WS-rm126-xx-1982A	10	17	---	50	---	96	135	40	2.38	39.50	skewed to coarse	----	poor
58.39	Sutter Butte Riffle	WS-rm017-xx-1982A	10	27	---	70	---	117	170	56	2.08	45.00	skewed to coarse	----	poor
58.36	Sutter Butte Riffle	WS-rm120-xx-1982A	5	9	---	24	---	44	61	20	2.17	17.45	skewed to coarse	----	moderate
58.34	Sutter Butte Riffle	WS-rm018-xx-1982A	3	11	---	33	---	53	70	24	2.20	21.00	skewed to fine	----	poor

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River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
57.40	Big Hole	WS-rb128-xx-1982A	17	34	---	77	---	160	200	74	2.17	63.00	very skewed to coarse	----	poor
57.39	Big Hole	WS-rb025-xx-1982A	14	49	---	107	---	185	270	95	1.95	68.25	very skewed to coarse	----	poor
57.38	Big Hole	WS-rb026-xx-1982A	10	17	---	39	---	63	82	33	1.93	23.00	skewed to coarse	----	moderate
57.20	Conveyor Belt Riffle	WS-rt027-xx-1982A	12	18	---	31	---	92	120	41	2.25	36.88	symmetrical	----	poor
57.20	Conveyor Belt Riffle	WS-rt028-xx-1982A	6	17	---	62	---	120	180	45	2.66	51.50	skewed to coarse	----	moderate
57.17	Conveyor Belt Riffle	WS-rm123-xx-1982A	17	30	---	76	---	130	160	62	2.08	50.00	very skewed to coarse	----	poor
57.16	Conveyor Belt Riffle	WS-bt022-xx-1982A	25	37	---	72	---	108	190	63	1.72	35.75	skewed to fine	----	moderate
56.93	Conveyor Belt/Hour (upper)	WS-bb029-xx-1982A	3	8	---	17	---	39	60	18	2.17	15.38	skewed to coarse	----	moderate
56.90	Conveyor Belt/Hour (upper)	WS-bt129-xx-1982A	13	23	---	54	---	91	120	45	2.01	34.25	very skewed to coarse	----	moderate
56.72	Hour Riffle (upper)	WS-bt130-xx-1982A	2	7	---	40	---	105	150	27	3.82	48.90	skewed to coarse	----	poor
56.71	Hour Riffle (upper)	WS-rt030-xx-1982A	16	27	---	38	---	83	105	47	1.75	28.00	very skewed to coarse	----	poor
56.60	Hour Riffle (upper)	WS-rm131-xx-1982A	13	23	---	50	---	89	120	45	1.99	33.25	skewed to coarse	----	poor
56.60	Hour Riffle (upper)	WS-rm132-xx-1982A	11	26	---	65	---	85	110	47	1.81	29.50	skewed to coarse	----	poor
56.59	Hour Riffle (upper)	WS-rm133-xx-1982A	10	15	---	43	---	77	105	34	2.24	30.80	skewed to coarse	----	poor
56.57	Hour Riffle (upper)	WS-rm031-xx-1982A	3	11	---	41	---	76	100	28	2.69	32.75	very skewed to coarse	----	poor
56.55	Hour Riffle (upper)	WS-rm032-xx-1982A	12	17	---	45	---	84	120	38	2.22	33.50	very skewed to coarse	----	moderate
56.39	Hour Riffle (upper)	WS-bb134-xx-1982A	9	18	---	43	---	86	115	39	2.19	34.00	very skewed to coarse	----	moderate
56.36	Hour Riffle (upper)	WS-bb033-xx-1982A	17	31	---	68	---	129	210	63	2.04	49.00	skewed to coarse	----	moderate

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River Mile (USACE)	Riffle/Feature	Office Code*	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
56.31	Hour Riffle (upper)	WS-rb034-xx-1982A	11	19	---	66	---	132	165	49	2.67	56.75	skewed to coarse	----	moderate
56.10	Hour Riffle (lower)	WS-bt035-xx-1982A	9	21	---	48	---	72	89	38	1.87	25.75	very skewed to coarse	----	moderate
55.82	Hour Riffle (lower)	WS-bm135-xx-1982A	16	36	---	68	---	98	120	59	1.65	31.00	skewed to coarse	----	poor
55.81	Hour Riffle (lower)	WS-rt036-xx-1982A	17	32	---	66	---	108	160	58	1.85	38.25	skewed to coarse	----	moderate
55.74	Hour Riffle (lower)	WS-rm037-xx-1982A	11	19	---	40	---	66	82	35	1.89	23.75	skewed to coarse	----	poor
55.69	Hour Riffle (lower)	WS-rb136-xx-1982A	11	20	---	45	---	69	83	37	1.86	24.50	very skewed to coarse	----	poor
54.79	Keister Riffle	WS-rt038-xx-1982A	5	14	---	31	---	54	74	27	2.00	20.25	very skewed to coarse	----	poor
54.75	Keister Riffle	WS-rt039-xx-1982A	9	17	---	46	---	110	155	43	2.58	46.75	skewed to coarse	----	moderate
54.61	Keister Riffle	WS-bm137-xx-1982A	23	32	---	64	---	114	150	60	1.89	41.00	very skewed to coarse	----	poor
54.60	Keister Riffle	WS-rb139-xx-1982A	11	18	---	49	---	87	115	40	2.17	34.30	very skewed to coarse	----	poor
54.59	Keister Riffle	WS-rb138-xx-1982A	7	15	---	41	---	68	84	32	2.15	26.65	skewed to coarse	----	moderate
54.58	Keister Riffle	WS-bm040-xx-1982A	15	27	---	58	---	96	130	51	1.89	34.50	skewed to coarse	----	moderate
54.56	Keister Riffle	WS-bm041-xx-1982A	10	32	---	66	---	108	145	59	1.84	38.00	very skewed to coarse	----	poor
54.37	Goose Riffle	WS-bt140-xx-1982A	10	27	---	67	---	100	130	51	1.94	36.75	very skewed to coarse	----	poor
54.29	Goose Riffle	WS-bt141-xx-1982A	11	21	---	64	---	110	150	48	2.29	44.50	skewed to coarse	----	moderate
53.61	Big Riffle	WS-bt142-xx-1982A	22	36	---	68	---	105	140	61	1.71	34.50	very skewed to coarse	----	poor
53.58	Big Riffle	WS-rt043A-xx-1982A	18	36	---	74	---	119	150	65	1.82	41.50	skewed to coarse	----	poor
53.57	Big Riffle	WS-bt143-xx-1982A	4	13	---	40	---	77	100	32	2.43	32.00	skewed to coarse	----	moderate

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River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	D_g (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
52.98	Big Riffle	WS-rt043B-xx-1982A	1	14	---	48	---	81	107	34	2.41	33.50	skewed to coarse	----	poor
52.96	Big Riffle	WS-rt144-xx-1982A	16	24	---	45	---	73	100	42	1.74	24.50	very skewed to coarse	----	poor
52.91	Big/MacFarland (upper)	WS-bt044-xx-1982A	9	29	---	66	---	110	149	56	1.95	40.50	very skewed to coarse	----	poor
52.27	MacFarland Riffle (upper)	WS-rt145-xx-1982A	2	8	---	17	---	36	64	17	2.10	13.90	very skewed to coarse	----	poor
52.27	MacFarland Riffle (upper)	WS-rt146-xx-1982A	8	20	---	40	---	66	82	36	1.82	23.00	very skewed to coarse	----	moderate
52.26	MacFarland Riffle (upper)	WS-rt045-xx-1982A	5	11	---	27	---	47	64	23	2.04	17.88	very skewed to coarse	----	moderate
52.24	MacFarland Riffle (upper)	WS-rt046-xx-1982A	8	25	---	66	---	110	150	52	2.10	42.50	very skewed to coarse	----	poor
52.24	MacFarland Riffle (upper)	WS-rt047-xx-1982A	4	11	---	38	---	66	82	27	2.48	27.63	symmetrical	----	poor
52.22	MacFarland Riffle (upper)	WS-rt147-xx-1982A	9	15	---	60	---	97	130	38	2.54	41.00	very skewed to coarse	----	poor
52.21	MacFarland Riffle (upper)	WS-rt148-xx-1982A	11	22	---	55	---	82	105	43	1.92	29.85	symmetrical	----	moderate
52.04	MacFarland Riffle (upper)	WS-rm149-xx-1982A	10	22	---	52	---	82	100	43	1.91	29.80	skewed to coarse	----	poor
52.03	MacFarland Riffle (upper)	WS-rm150-xx-1982A	5	11	---	37	---	67	84	28	2.42	27.80	very skewed to coarse	----	poor
51.97	MacFarland Riffle (upper)	WS-rb048-xx-1982A	6	12	---	25	---	54	74	25	2.17	21.25	very skewed to coarse	----	moderate
50.55	GRIDLEY HIGHWAY BRIDGE														
49.53	Gridley Bridge Riffle	WS-bt050-xx-1982A	2	6	---	22	---	44	74	16	2.73	19.05	very skewed to coarse	----	poor
49.52	Gridley Bridge Riffle	WS-bt049-xx-1982A	10	20	---	35	---	67	94	37	1.83	23.50	very skewed to coarse	----	moderate
49.45	Gridley Bridge/Gridley Riffle	WS-bm151-xx-1982A	2	8	---	19	---	45	70	19	2.34	18.40	very skewed to coarse	----	moderate
49.37	Gridley Riffle	WS-rt051a-xx-1982A	9	14	---	35	---	74	98	32	2.30	30.00	skewed to coarse	----	moderate

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River Mile (USACE)	Riffle/Feature	Office Code*	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
49.37	Gridley Riffle	WS-rb055-xx-1982A	8	18	---	45	---	72	97	35	2.03	27.25	skewed to coarse	----	moderate
49.36	Gridley Riffle	WS-rb162-xx-1982A	12	21	---	48	---	76	100	40	1.90	27.50	very skewed to coarse	----	poor
49.36	Gridley Riffle	WS-rt051b-xx-1982A	7	13	---	34	---	66	80	29	2.25	26.50	very skewed to coarse	----	poor
49.36	Gridley Riffle	WS-bb152-xx-1982A	4	12	---	33	---	47	59		2.00	17.60	very skewed to coarse	----	poor
49.34	Gridley Riffle	WS-rb054-xx-1982A	5	13	---	38	---	72	97	30	2.40	29.75	skewed to coarse	----	poor
49.33	Gridley Riffle	WS-bm053-xx-1982A	11	21	---	46	---	72	90	39	1.85	25.50	very skewed to coarse	----	poor
49.30	Gridley Riffle	WS-bm154-xx-1982A	10	21	---	45	---	70	85	38	1.83	24.50	skewed to coarse	----	poor
49.12	Gridley Riffle	WS-rm157-xx-1982A	7	13	---	27	---	44	61	24	1.85	15.65	skewed to coarse	----	poor
49.12	Gridley Riffle	WS-bb156-xx-1982A	8	16	---	33	---	56	74	30	1.87	20.00	skewed to coarse	----	poor
49.09	Gridley Riffle	WS-bm056-xx-1982A	3	8	---	35	---	66	82	23	2.87	29.00	skewed to coarse	----	moderate
48.66	Junkyard Riffle (upper)	WS-rt057-xx-1982A	2	11	---	35	---	68	84	27	2.49	28.50	very skewed to coarse	----	poor
48.64	Junkyard Riffle (upper)	WS-rt158-xx-1982A	7	21	---	50	---	74	90	39	1.88	26.50	very skewed to coarse	----	poor
48.63	Junkyard Riffle (upper)	WS-bt058-xx-1982A	10	15	---	36	---	68	84	31	2.17	26.75	very skewed to coarse	----	moderate
48.62	Junkyard Riffle (upper)	WS-rt159-xx-1982A	4	9	---	37	---	62	78	23	2.64	26.55	very skewed to coarse	----	poor
48.62	Junkyard Riffle (upper)	WS-rt059-xx-1982A	3	10	---	22	---	40	54	20	2.04	15.20	skewed to coarse	----	moderate
48.60	Junkyard Riffle (upper)	WS-rt060-xx-1982A	3	8	---	17	---	29	37	15	1.94	10.45	very skewed to coarse	----	poor
48.56	Junkyard Riffle (upper)	WS-rt160-xx-1982A	4	15	---	34	---	64	80	31	2.07	24.50	very skewed to fine	----	moderate
48.48	Junkyard Riffle (upper)	WS-bm062B-xx-1982A	14	28	---	51	---	81	105	48	1.70	26.50	skewed to coarse	----	poor

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River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	D_g (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
48.34	Junkyard (upper)/Herringer	WS-rb161-xx-1982A	2	13	---	30	---	54	72	26	2.08	20.75	skewed to coarse	----	poor
48.33	Junkyard (upper)/Herringer	WS-bm062A-xx-1982A	2	13	---	45	---	70	89	30	2.32	28.50	very skewed to coarse	----	poor
48.32	Junkyard (upper)/Herringer	WS-rb061-xx-1982A	2	13	---	47	---	78	100	32	2.45	32.50	very skewed to coarse	----	moderate
47.99	Junkyard Riffle (lower)	WS-rt164-xx-1982A	4	17	---	31	---	47	66	28	1.66	15.00	skewed to coarse	----	poor
47.97	Junkyard Riffle (lower)	WS-rm063-xx-1982A	6	19	---	45	---	78	100	38	2.03	29.50	skewed to coarse	----	poor
47.96	Junkyard Riffle (lower)	WS-rm163-xx-1982A	8	14	---	28	---	44	58	25	1.77	14.85	skewed to coarse	----	poor
47.94	Junkyard Riffle (lower)	WS-rm064-xx-1982A	7	22	---	46	---	74	105	40	1.86	26.25	skewed to coarse	----	moderate
47.49	Herringer Riffle (upper)	WS-bt065-xx-1982A	7	9	---	12	---	35	50	17	2.02	13.20	very skewed to coarse	----	moderate
47.28	Herringer (upper)/Herringer (lower)	WS-rm066-xx-1982A	6	13	---	29	---	51	70	26	1.98	19.00	very skewed to coarse	----	poor
46.46	Herringer Riffle (lower)	WS-rt165-xx-1982A	5	16	---	40	---	74	105	34	2.18	29.25	skewed to coarse	----	poor
46.45	Herringer Riffle (lower)	WS-rt166-xx-1982A	4	14	---	34	---	54	70	27	1.96	20.00	very skewed to coarse	----	poor
46.22	Herringer Riffle (lower)	WS-rm068-xx-1982A	11	22	---	45	---	70	87	39	1.78	24.00	skewed to coarse	----	poor
46.12	Herringer Riffle (lower)	WS-bb167-xx-1982A	8	14	---	34	---	65	80	30	2.18	25.65	skewed to coarse	----	poor
46.10	Herringer Riffle (lower)	WS-rb069-xx-1982A	5	16	---	31	---	54	73	29	1.84	19.00	very skewed to coarse	----	poor
45.24	Herringer (lower)/Honcut Creek	WS-rt168-xx-1982A	3	10	---	25	---	48	69	21	2.24	19.20	very skewed to coarse	----	poor
44.89	Herringer (lower)/Honcut Creek	WS-rb169-xx-1982A	6	12	---	22	---	39	58	22	1.80	13.50	very skewed to coarse	----	poor
44.85	Herringer (lower)/Honcut	WS-rb170-xx-1982A	4	12	---	27	---	38	45	21	1.78	13.00	very skewed to coarse	----	moderate

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River Mile (USACE)	Riffle/Feature	Office Code*	D_5 (mm)	D_{16} (mm)	D_{25} (mm)	D_{50} (mm)	D_{75} (mm)	D_{84} (mm)	D_{95} (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
	Creek														
44.82	Herringer (lower)/Honcut Creek	WS-rb070-xx-1982A	3	10	---	21	---	35	43	18	1.91	12.70	very skewed to coarse	----	poor
44.78	Herringer (lower)/Honcut Creek	WS-bt171-xx-1982A	4	14	---	30	---	56	84	28	1.99	20.90	skewed to coarse	----	moderate
44.39	Herringer (lower)/Honcut Creek	WS-rt071-xx-1982A	1	10	---	33	---	47	60	22	2.17	18.50	very skewed to coarse	----	poor
44.315	HONCUT CREEK														

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Table 5.3-4. Wolman Samples of Tailings Collected between Thermalito Diversion Dam and Honcut Creek in 2002/03.

River Mile (USACE)	Riffle/Feature	Office Code	D5 (mm)	D16 (mm)	D25 (mm)	D50 (mm)	D75 (mm)	D84 (mm)	D95 (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
* "Office Code" is defined sequentially by the following: 1) Type of sample --- BS = bulk sample, WS = Wolman sample; 2) Feature --- r = riffle, b = bar, g = glide, t = tailings, blank = unspecified; 3) Location --- t = top (upstream) end of feature, m = middle of feature, b = bottom (downstream) end of feature, blank = unspecified; 4) Number --- consecutive numbering consistent in 1982, 1996, 2002/2003;		5) Local feature --- d = dune, t = trough, e = embedded, blank = unspecified; 6) Year--- year that this site was last sampled --- main years of sampling are 1982, 1996 and 2002/2003, xx means this is the first year sampled; 7) Year--- year that this sample was taken; 8) Vertical stratum sampled --- A = surface, B = subsurface, C = both													
71.500	OROVILLE DAM														
67.128	THERMALITO DIVERSION DAM														
66.541	FISH BARRIER DAM														
66.283	TABLE MOUNTAIN BRIDGE														
65.002	HIGHWAY 70 BRIDGE														
63.872	HIGHWAY 162 BRIDGE														
63.199	Mathews/Aleck Tailings	WS-TP-t002-xx-2003A	16	31	39	59	90	109	152	58.1	1.88	39.26	symmetrical	normal	moderate
63.167	Mathews/Aleck Tailings	WS-TP-t001-xx-2003A	9	16	24	46	70	83	121	36.2	2.30	33.82	skewed towards coarse	normal	poor
58.729	Thermalito Outflow Tailings	WS-TP-t006s-xx-2003A	0	5	7	18	34	44	81	14.5	3.00	19.40	very skewed towards coarse	very highly peaked	extremely poor
58.722	THERMALITO SPILLWAY														
58.681	Thermalito Outflow Tailings	WS-TP-t007-xx-2003A	22	38	50	78	113	128	170	69.4	1.84	45.05	skewed towards coarse	normal	moderate

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River Mile (USACE)	Riffle/Feature	Office Code	D$_5$ (mm)	D$_{16}$ (mm)	D$_{25}$ (mm)	D$_{50}$ (mm)	D$_{75}$ (mm)	D$_{84}$ (mm)	D$_{95}$ (mm)	Dg (mm)	Sigma - root of percentile method	Standard Deviation (mm)	Description of Skewness (negative = coarser, positive = finer) (Warren, 1974)	Description of Kurtosis --- Frequency Distribution (Folk and Ward, 1957)	Description of Sorting (Folk and Ward, 1957)
53.887	Goose Backwater Tailings	WS-TP-t005n-xx-2003A	7	34	42	65	99	113	147	62.4	1.82	39.59	skewed towards coarse	highly peaked	poor
53.887	Goose Backwater Tailings	WS-TP-t005s-xx-2003A	4	10	22	43	69	81	118	29.0	2.78	35.15	very skewed towards coarse	highly peaked	poor
53.887	Goose Backwater Tailings	WS-TP-t005-xx-2003C	5	23	35	56	86	104	139	49.3	2.11	40.24	very skewed towards coarse	highly peaked	poor
50.545	GRIDLEY HIGHWAY BRIDGE														

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5.4   SPAWNING GRAVEL QUALITY

Much has been written about salmon spawning gravel quality. Quality indicators such as the geometric mean diameter (Shirazi, Seim, and Lewis 1981) and the fredle index (Lotspeich and Everest 1981) are used. The single variable descriptors may not be sufficient if the sample size distribution is not lognormal. For non-lognormal samples, the first and second standard deviation, skewness and kurtosis are required to adequately describe the sample. Most spawning gravel quality indices are specific about the amount of fine sediment that is acceptable, but few specify the amount of allowable cobble and boulder fractions.

Several researchers have investigated the size range or dimensions of gravel suitable for salmon spawning. Shirazi et al (1981) observed that a ratio of gravel diameter (Dg) to egg diameter (De) provides a strong correlation with embryo survival. Figure 5.4-1 shows that egg to alevin survival increases with an increase in the Dg/De ratio in redds.
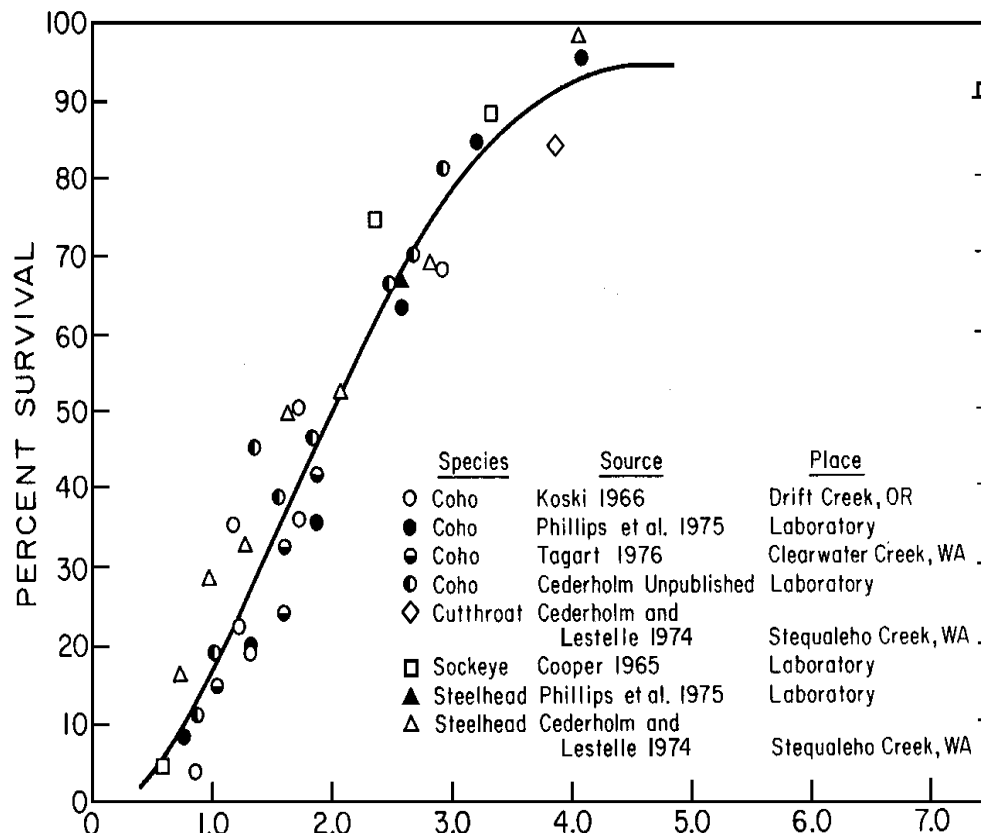

Figure 5.4-1 Egg to Alevin Survival as a Function of Gravel Diameter.

Maximum survival occurs with a ratio approaching 4. Chinook egg diameters range

from 6.3 to 7.9 mm (0.25 to 0.31 in) which indicates that maximum survival occurs in redds with a Dg above about 25 mm, or about 0.5 inches. No data are available on the upper coarseness limit.

Table 5.4-1 shows the gravel quality developed from the Dg and the Dg\De ratios for all the sieve analyses done during this study. The Table also shows the gravel quality developed from other quality criteria.

Table 5.4-1. Summary of Quality Criteria for the 2002-03 Bulk Sampling

River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
			<=30 %	>=40 %	<50 %	<= 20 %	<= 20 %	<= 20 %	<= 20 %	70 - 100 %	70 - 100 %	70 - 100 %	<10 % and >20%	GOOD
			30-40%	20-40%	50-80%	20-25%	20-25%	20-25%	20-40%	50 - 70 %	50 - 70 %	50 - 70 %		FAIR
			>= 40 %	<= 20 %	>=80 %	>= 25 %	>= 25 %	>= 25 %	>=40 %	0 - 50 %	0 - 50 %	0 - 50 %	10 - 20 %	POOR
71.50	OROVILLE DAM													
67.13	THERMALITO DIVERSION DAM													
66.54	FISH BARRIER DAM													
66.28	TABLE MOUNTAIN BRIDGE													
66.03	Hatchery Riffle	BS-rt001-96-2003A	45	33	21	1	1	0	2	n/a	95	91	0.1	FAIR
66.03	Hatchery Riffle	BS-rt001-96-2003B	13	21	34	12	11	8	32	95	95	81	4.8	FAIR
66.03	Hatchery Riffle	BS-rt001-96-2003C	29	27	27	7	6	4	17	n/a	95	91	2.4	FAIR
65.77	Moes' Ditch	BS-bb002-82-2002A	0	36	43	11	6	4	22	n/a	95	91	2.6	FAIR
65.77	Moes' Ditch	BS-bb002-82-2002B	0	7	37	17	21	18	56	54	87	33	10.9	POOR
65.77	Moes' Ditch	BS-bb002-82-2002C	0	21	39	15	13	11	39	88	93	74	6.7	FAIR
65.76	Auditorium Riffle	BS-rt002t-96-2002A	63	28	5	2	1	1	4	n/a	95	91	0.5	POOR
65.76	Auditorium Riffle	BS-rt002t-96-2002B	0	8	39	17	14	21	53	41	84	38	12.9	POOR
65.76	Auditorium Riffle	BS-rt002t-96-2002C	31	18	22	9	8	11	29	n/a	95	81	6.7	FAIR
65.76	Auditorium Riffle	BS-rt002dt-96-2002A	31	34	27	6	2	1	8	n/a	95	91	0.4	GOOD
65.76	Auditorium Riffle	BS-rt002dt-96-2002B	3	9	40	17	14	16	49	57	90	53	10.1	POOR

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner---% of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner---% of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner---% of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner---% of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner---% of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner---% of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner---% of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
65.76	Auditorium Riffle	BS-rt002dt-96-2002C	17	21	33	12	8	9	29	n/a	95	85	5.3	FAIR
65.76	Auditorium Riffle	BS-rt002d-96-2002A	0	39	48	10	2	0	13	n/a	95	91	0.3	GOOD
65.76	Auditorium Riffle	BS-rt002d-96-2002B	6	10	41	17	14	12	44	80	93	71	7.4	POOR
65.76	Auditorium Riffle	BS-rt002d-96-2002C	3	24	44	14	8	6	29	95	95	88	3.8	FAIR
65.23	Bedrock Park Riffle	BS-gm003-82-2003A	68	18	9	2	2	1	5	n/a	95	91	1.0	POOR
65.23	Bedrock Park Riffle	BS-gm003-82-2003B	10	18	32	14	12	13	39	90	93	72	7.9	FAIR
65.23	Bedrock Park Riffle	BS-gm003-82-2003C	39	18	21	8	7	7	22	n/a	95	87	4.4	FAIR
65.00	HIGHWAY 70 BRIDGE													
64.27	River Run Park Pool	BS-pb001-xx-2003A	0	28	59	9	3	0	13	n/a	95	91	0.2	GOOD
63.87	HIGHWAY 162 BRIDGE													
63.47	Mathews Riffle	BS-rt004-96-2002A	29	45	21	3	1	0	5	n/a	95	91	0.2	GOOD
63.47	Mathews Riffle	BS-rt004-96-2002B	10	25	25	13	14	12	40	90	92	65	7.0	POOR
63.47	Mathews Riffle	BS-rt004-96-2002C	19	35	23	8	8	6	22	n/a	95	87	3.6	FAIR
62.89	Aleck Riffle	BS-rt005-96-2003A	23	22	26	4	3	1	8	n/a	95	91	0.7	FAIR
62.89	Aleck Riffle	BS-rt005-96-2003B	18	22	30	8	10	12	31	94	94	76	7.8	FAIR
62.89	Aleck Riffle	BS-rt005-96-2003C	17	22	28	6	6	7	19	n/a	95	88	4.3	FAIR
62.78	Aleck Riffle	BS-gt005-82-2003A	49	27	19	3	2	0	5	n/a	95	91	0.3	FAIR
62.78	Aleck Riffle	BS-gt005-82-2003B	8	11	33	15	17	15	48	75	90	47	8.6	POOR
62.78	Aleck Riffle	BS-gt005-82-2003C	28	19	26	9	9	8	27	n/a	95	84	4.4	FAIR
62.62	Aleck Tailings	BS-TP-bm009-xx-2003A	29	38	20	5	3	4	13	n/a	95	91	2.0	GOOD

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi--- Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn--- embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
62.62	Aleck Tailings	BS-TP-bm009-xx-2003B	11	15	23	12	15	21	52	57	73	26	11.7	POOR
62.62	Aleck Tailings	BS-TP-bm009-xx-2003C	20	26	21	8	9	12	32	93	92	73	6.8	FAIR
61.38	Robinson Riffle (upper)	BS-rt006-xx-2003A	10	48	31	6	4	1	11	n/a	95	91	0.5	GOOD
61.38	Robinson Riffle (upper)	BS-rt006-xx-2003B	4	8	38	18	21	12	51	75	92	51	6.9	POOR
61.38	Robinson Riffle (upper)	BS-rt006-xx-2003C	7	28	34	12	12	6	31	95	95	83	3.7	FAIR
61.14	Robinson Riffle (lower)	BS-bt007d-xx-2003A	72	19	5	1	2	1	5	n/a	95	91	0.8	POOR
61.14	Robinson Riffle (lower)	BS-bt007d-xx-2003B	4	17	28	12	14	20	51	38	67	29	9.3	POOR
61.14	Robinson Riffle (lower)	BS-bt007d-xx-2003C	38	18	16	7	8	11	28	95	93	78	5.0	FAIR
61.14	Robinson Riffle (lower)	BS-bt007dt-xx-2003A	45	27	17	4	4	3	11	n/a	95	91	1.8	FAIR
61.14	Robinson Riffle (lower)	BS-bt007dt-xx-2003B	4	13	31	13	14	20	52	35	69	31	9.2	POOR
61.14	Robinson Riffle (lower)	BS-bt007dt-xx-2003C	25	20	24	9	9	12	31	94	92	76	5.5	FAIR
61.14	Robinson Riffle (lower)	BS-bt007t-xx-2003A	18	36	29	6	6	5	17	n/a	95	90	2.8	GOOD
61.14	Robinson Riffle (lower)	BS-bt007t-xx-2003B	4	10	34	15	14	20	52	31	71	33	9.2	POOR
61.14	Robinson Riffle (lower)	BS-bt007t-xx-2003C	11	23	31	10	10	13	35	88	92	72	6.0	FAIR
60.71	Steep Riffle	BS-rt008t-96-2003A	4	51	33	7	4	2	12	n/a	95	91	0.8	GOOD
60.71	Steep Riffle	BS-rt008t-96-2003B	7	18	42	16	9	8	34	95	95	85	4.0	FAIR
60.71	Steep Riffle	BS-rt008t-96-2003C	5	34	37	11	6	5	23	n/a	95	91	2.4	FAIR
60.71	Steep Riffle	BS-rt008dt-96-	2	33	51	8	4	2	14	n/a	95	91	0.9	GOOD

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi--- Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn--- embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
		2003A												
60.71	Steep Riffle	BS-rt008dt-96-2003B	4	15	47	14	9	10	34	92	94	82	5.1	FAIR
60.71	Steep Riffle	BS-rt008dt-96-2003C	3	24	49	11	6	6	24	95	95	90	3.0	FAIR
60.71	Steep Riffle	BS-rt008d-96-2003A	0	16	70	9	4	2	15	n/a	95	91	1.0	FAIR
60.71	Steep Riffle	BS-rt008d-96-2003B	0	13	52	13	8	13	35	79	93	78	6.2	FAIR
60.71	Steep Riffle	BS-rt008d-96-2003C	0	14	61	11	6	7	25	94	95	88	3.6	FAIR
60.49	Weir Riffle	BS-bm009t-82-2003A	0	60	28	6	4	2	13	n/a	95	91	1.3	GOOD
60.49	Weir Riffle	BS-bm009t-82-2003B	0	29	37	12	10	12	34	91	93	78	6.5	FAIR
60.49	Weir Riffle	BS-bm009t-82-2003C	0	44	32	9	7	7	24	n/a	95	88	3.9	FAIR
60.49	Weir Riffle	BS-bm009dt-82-2003A	0	35	49	10	5	3	17	n/a	95	91	1.7	GOOD
60.49	Weir Riffle	BS-bm009dt-82-2003B	0	15	40	15	11	18	45	48	90	57	9.5	POOR
60.49	Weir Riffle	BS-bm009dt-82-2003C	0	25	44	12	8	10	31	94	95	83	5.6	FAIR
60.49	Weir Riffle	BS-bm009d-82-2003A	0	9	70	13	5	3	21	95	95	91	2.1	FAIR
60.49	Weir Riffle	BS-bm009d-82-2003B	0	2	43	17	13	23	55	28	94	35	12.5	POOR
60.49	Weir Riffle	BS-bm009d-82-2003C	0	6	56	15	9	13	38	77	93	77	7.3	FAIR
59.97	Eye Riffle	BS-rm021-96-2003A	24	38	28	4	2	3	10	n/a	95	91	1.1	GOOD
59.97	Eye Riffle	BS-rm021-96-2003B	5	21	27	11	14	19	48	51	80	34	8.5	POOR
59.97	Eye Riffle	BS-rm021-96-2003C	14	29	28	8	8	11	29	94	93	78	4.8	FAIR

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
59.49	Gateway Riffle	BS-rt010-96-2003A	21	46	28	3	1	0	5	n/a	95	91	0.2	GOOD
59.49	Gateway Riffle	BS-rt010-96-2003B	2	25	38	9	10	15	34	83	74	70	9.7	FAIR
59.49	Gateway Riffle	BS-rt010-96-2003C	12	35	33	6	6	8	20	n/a	95	88	4.9	GOOD
58.72	THERMALITO SPILLWAY													
58.41	Sutter Butte Riffle	BS-rt011-82-2003A	2	39	51	6	1	0	8	n/a	95	91	0.1	GOOD
58.41	Sutter Butte Riffle	BS-rt011-82-2003B	4	25	28	15	14	14	43	85	92	64	7.2	POOR
58.41	Sutter Butte Riffle	BS-rt011-82-2003C	3	32	39	10	8	7	25	95	95	87	3.6	FAIR
58.39	Sutter Butte Riffle	BS-rt011-96-2003A	0	21	57	10	8	4	22	95	95	91	2.3	FAIR
58.39	Sutter Butte Riffle	BS-rt011-96-2003B	18	24	34	10	7	6	24	n/a	95	88	3.6	FAIR
58.39	Sutter Butte Riffle	BS-rt011-96-2003C	9	22	46	10	8	5	23	n/a	95	90	3.0	FAIR
57.17	Conveyor Belt Riffle	BS-rt012t-82-2003A	34	36	22	5	3	1	8	n/a	95	91	0.5	FAIR
57.17	Conveyor Belt Riffle	BS-rt012t-82-2003B	0	10	28	22	28	11	62	69	90	34	6.7	POOR
57.17	Conveyor Belt Riffle	BS-rt012t-82-2003C	17	23	25	13	16	6	35	95	95	79	3.6	FAIR
57.17	Conveyor Belt Riffle	BS-rt012dt-82-2003A	17	27	44	7	3	2	12	n/a	95	91	1.0	GOOD
57.17	Conveyor Belt Riffle	BS-rt012dt-82-2003B	3	15	32	17	20	12	50	79	91	50	7.5	POOR
57.17	Conveyor Belt Riffle	BS-rt012dt-82-2003C	10	21	38	12	12	7	31	95	95	83	4.2	FAIR
57.17	Conveyor Belt Riffle	BS-rt012d-xx-2003A	0	19	65	9	4	2	16	n/a	95	91	1.5	FAIR

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi--- Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn--- embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
57.17	Conveyor Belt Riffle	BS-rt012d-xx-2003B	5	21	36	13	12	13	39	87	93	70	8.2	FAIR
57.17	Conveyor Belt Riffle	BS-rt012d-xx-2003C	3	20	50	11	8	8	27	95	95	86	4.9	FAIR
56.33	Hour Riffle (upper)	BS-rm013d-96-2003A	5	31	34	11	11	7	30	95	95	84	3.7	FAIR
56.33	Hour Riffle (upper)	BS-rm013d-96-2003B	9	27	28	12	15	9	36	94	93	74	5.3	FAIR
56.33	Hour Riffle (upper)	BS-rm013d-96-2003C	7	29	31	12	13	8	33	94	95	79	4.5	FAIR
56.33	Hour Riffle (upper)	BS-rm013dt-96-2003A	20	28	27	9	9	6	25	n/a	95	87	3.0	FAIR
56.33	Hour Riffle (upper)	BS-rm013dt-96-2003B	11	21	29	12	15	11	39	92	92	66	5.9	FAIR
56.33	Hour Riffle (upper)	BS-rm013dt-96-2003C	16	25	28	11	12	9	32	95	94	79	4.5	FAIR
56.32	Hour Riffle (upper)	BS-rm013t-96-2003A	36	26	19	7	7	5	19	n/a	95	89	2.4	FAIR
56.32	Hour Riffle (upper)	BS-rm013t-96-2003B	13	16	30	13	15	13	42	88	91	58	6.6	POOR
56.32	Hour Riffle (upper)	BS-rm013t-96-2003C	24	21	24	10	11	9	31	95	94	79	4.5	FAIR
54.66	Keister Riffle	BS-rt014-82-2003A	24	30	38	5	2	1	8	n/a	95	91	0.4	GOOD
54.66	Keister Riffle	BS-rt014-82-2003B	0	22	38	14	12	13	40	80	92	67	6.6	POOR
54.66	Keister Riffle	BS-rt014-82-2003C	12	26	38	9	7	7	24	n/a	95	87	3.5	FAIR
54.45	Goose Riffle	BS-bb015-96-2003A	2	30	56	6	3	1	12	n/a	95	91	0.5	GOOD
54.45	Goose Riffle	BS-bb015-96-2003B	0	7	27	15	19	27	66	15	23	0	8.7	POOR
54.45	Goose Riffle	BS-bb015-96-2003C	1	18	41	11	11	14	39	60	87	58	4.6	FAIR
54.40	Goose Riffle	BS-rt015-82-2003A	0	4	60	15	12	7	35	87	94	81	2.3	FAIR
54.40	Goose Riffle	BS-rt015-82-2003B	0	3	43	25	21	6	54	77	92	69	1.2	POOR

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River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
54.40	Goose Riffle	BS-rt015-82-2003C	0	4	52	20	16	6	44	83	93	77	1.8	POOR
53.89	Goose Backwater Tailings	BS-TP-bm004t-xx-2003A	10	33	34	8	6	5	23	n/a	95	87	2.4	FAIR
53.89	Goose Backwater Tailings	BS-TP-bm004t-xx-2003B	0	2	29	22	19	19	69	9	38	0	7.6	POOR
53.89	Goose Backwater Tailings	BS-TP-bm004t-xx-2003C	5	18	31	15	13	12	46	57	83	53	5.0	POOR
53.89	Goose Backwater Tailings	BS-TP-bm004dt-xx-2003A	9	40	29	8	7	5	22	n/a	95	87	2.8	FAIR
53.89	Goose Backwater Tailings	BS-TP-bm004dt-xx-2003B	0	2	33	21	19	18	65	17	56	18	8.3	POOR
53.89	Goose Backwater Tailings	BS-TP-bm004dt-xx-2003C	4	21	31	14	13	12	44	77	88	58	5.6	POOR
53.88	Goose Backwater Tailings	BS-TP-bm004d-xx-2003A	8	46	25	7	7	6	21	n/a	95	87	3.3	FAIR
53.88	Goose Backwater Tailings	BS-TP-bm004d-xx-2003B	0	2	37	20	19	17	61	31	72	28	9.0	POOR
53.88	Goose Backwater Tailings	BS-TP-bm004d-xx-2003C	28	19	26	9	8	9	28	95	95	83	4.5	FAIR
53.63	Big Riffle	BS-rt017t-96-2003A	16	54	20	5	3	1	10	n/a	95	91	0.6	GOOD
53.63	Big Riffle	BS-rt017t-96-2003B	13	11	32	14	16	13	44	85	90	54	6.3	POOR
53.63	Big Riffle	BS-rt017t-96-2003C	15	32	26	9	9	7	27	95	95	84	3.5	FAIR
53.63	Big Riffle	BS-rt017dt-96-	8	48	33	6	4	1	11	n/a	95	91	0.6	GOOD

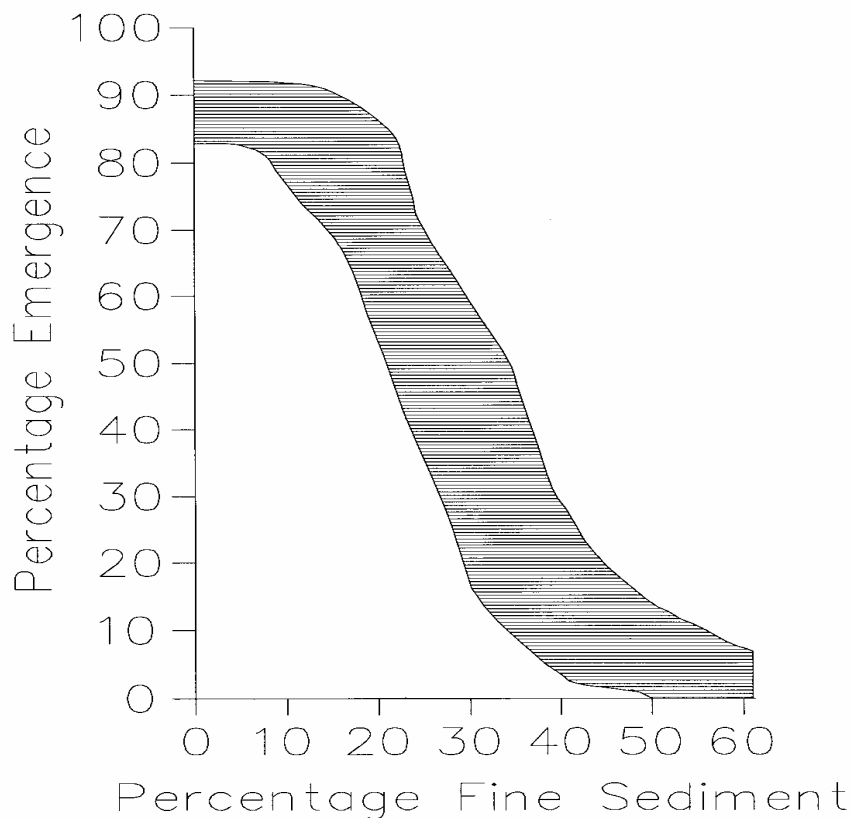| River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner---% of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner---% of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner---% of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner---% of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner---% of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner---% of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner---% of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz---% 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
		2003A												
53.63	Big Riffle	BS-rt017dt-96-2003B	7	13	35	15	17	11	45	85	91	60	5.8	POOR
53.63	Big Riffle	BS-rt017dt-96-2003C	8	30	34	11	10	6	28	95	95	85	3.2	FAIR
53.63	Big Riffle	BS-rt017d-96-2003A	0	41	47	7	4	1	12	n/a	95	91	0.7	GOOD
53.63	Big Riffle	BS-rt017d-96-2003B	2	16	38	17	17	10	45	84	93	67	5.3	POOR
53.63	Big Riffle	BS-rt017d-96-2003C	1	28	42	12	11	6	29	95	95	86	3.0	FAIR
53.59	Big Riffle	BS-bt017-82-2003A	11	44	25	6	6	5	19	n/a	95	89	2.5	GOOD
53.59	Big Riffle	BS-bt017-82-2003B	8	19	25	12	21	12	48	80	83	35	3.3	POOR
53.59	Big Riffle	BS-bt017-82-2003C	10	31	25	9	13	9	34	91	92	70	3.1	FAIR
53.58	Big Riffle	BS-bt016-82-2003A	10	52	31	3	2	1	7	n/a	95	91	0.5	GOOD
53.58	Big Riffle	BS-bt016-82-2003B	5	16	37	12	14	14	42	77	90	55	7.0	POOR
53.58	Big Riffle	BS-bt016-82-2003C	8	34	34	8	8	7	25	95	95	84	3.7	FAIR
52.32	MacFarland Riffle (upper)	BS-rt018-82-2003A	3	39	42	7	5	3	15	n/a	95	91	1.6	GOOD
52.32	MacFarland Riffle (upper)	BS-rt018-82-2003B	0	14	39	16	16	15	48	66	91	51	8.8	POOR
52.32	MacFarland Riffle (upper)	BS-rt018-82-2003C	2	27	40	11	11	9	31	94	95	81	5.2	FAIR
50.55	GRIDLEY HIGHWAY BRIDGE													
48.69	Junkyard Riffle (upper)	BS-rt020t-96-2003A	0	6	59	15	13	7	35	87	95	81	3.7	FAIR
48.69	Junkyard Riffle (upper)	BS-rt020t-96-2003B	0	4	30	17	22	25	66	28	62	0	12.1	POOR
48.69	Junkyard Riffle	BS-rt020t-96-2003C	0	5	44	16	17	16	51	54	86	44	7.9	POOR

River Mile (USACE)	Riffle/Feature	Office Code (CURRENT)	Warner--- % of sample 6 to 12 inches (152.4 to 304.8 mm)	Warner--- % of sample 3 to 6 inches (76.2 to 152.4 mm)	Warner--- % of sample 1 to 3 inches (25.4 to 76.2 mm)	Warner--- % of sample 0.5 to 1 inches (12.7 to 25.4 mm)	Warner--- % of sample 0.16 to 0.5 inches (4.06 to 12.7 mm)	Warner--- % of sample 0.015 to 0.16 inches (0.38 to 4.06 mm)	Warner--- % of sample less than 1.0 inches (0.0 to 25.4 mm)	Shirazi---Chinook embryo survivability (%) (based on Dg/De; De=7.1 mm)	Tappel and Bjornn---embryo survivability curves (% passing 9.5 mm vs. % passing 0.85 mm)	Bjornn and McCudden ---Chinook embryo survivability (%)	Hall and Lantz--- % 1-3 mm	OVERALL QUALITY RATING (qualitative based on overview of ratings)
	(upper)													
48.69	Junkyard Riffle (upper)	BS-rt020dt-96-2003A	0	5	57	15	13	10	38	83	93	76	4.7	FAIR
48.69	Junkyard Riffle (upper)	BS-rt020dt-96-2003B	0	6	32	17	20	22	62	31	66	0	10.7	POOR
48.69	Junkyard Riffle (upper)	BS-rt020dt-96-2003C	0	6	44	16	17	16	50	54	85	45	7.7	POOR
48.69	Junkyard Riffle (upper)	BS-rt020d-96-2003A	0	4	55	15	13	12	42	72	91	68	5.6	POOR
48.69	Junkyard Riffle (upper)	BS-rt020d-96-2003B	0	8	34	16	19	20	58	38	71	24	9.2	POOR
48.69	Junkyard Riffle (upper)	BS-rt020d-96-2003C	0	6	44	16	16	16	50	51	84	45	7.4	POOR
46.46	Herringer Riffle (lower)	BS-bb023-xx-2003A	0	10	53	16	11	8	37	85	94	80	4.1	FAIR
46.46	Herringer Riffle (lower)	BS-bb023-xx-2003B	0	1	27	17	18	33	71	15	36	0	16.4	POOR
46.46	Herringer Riffle (lower)	BS-bb023-xx-2003C	0	6	40	16	15	21	54	35	77	34	10.2	POOR
46.45	Herringer Riffle (lower)	BS-bb022/023-xx-2003A	0	6	53	17	14	9	42	80	93	76	5.1	POOR
46.45	Herringer Riffle (lower)	BS-bb022/023-xx-2003B	0	1	29	18	20	30	70	15	48	0	14.9	POOR
46.45	Herringer Riffle (lower)	BS-bb022/023-xx-2003C	0	3	41	18	17	20	56	38	80	34	10.0	POOR
46.45	Herringer Riffle (lower)	BS-bb022-xx-2003A	0	2	53	19	16	11	46	75	93	68	6.1	POOR
46.45	Herringer Riffle (lower)	BS-bb022-xx-2003B	0	1	31	19	21	26	68	15	58	0	13.3	POOR
46.45	Herringer Riffle (lower)	BS-bb022-xx-2003C	0	1	42	19	18	18	57	38	82	34	9.7	POOR
44.32	HONCUT CREEK													

Figure 5.4-2. Emergence as a Function of Fine Sediment

The Dg/De ratios for this study ranged to quite a bit larger than 5, suggesting that although the gravel meets embryo survival criteria for fine sediment, it may be too coarse.

According to Bjornn and Reiser (1991), upwards of 20 percent of the particles can be less than 6.35 mm (0.25 in) in diameter without significantly reducing embryo survival. The effect of fine sediment on fry emergence is shown in Figure 5.4-2.

The gravel quality tables showed the percent of each bulk sample finer than 6.4 mm (0.25 in). Two of the samples were more than 20 percent. The average of all the samples was about 11 percent, ranging from 1.6 to 22 percent. Dimensions of acceptable spawning gravel sizes based on percent by volume are shown in Table 6.4-4 (Puckett and Hinton 1974). The size range and volume of gravel was based on samples taken from Chinook salmon redds in the Eel River.

Table 5.4-2. Suitable Spawning Gravel for Chinook Salmon

TABLE VI		
Suitable Spawning Gravel for Chinook Salmon		
CENTIMETERS	GRAVEL SIZE (INCHES)	PERCENT BY VOLUME
15.2 to 30.5	6 to 12	30 or less
7.6 to 15.2	3 to 6	10 or more
2.5 to 7.6	1 to 3	50 or less
1.3 to 2.5	0.5 to 1	20 or less
0.4 to 1.3	0.16 to 0.5	20 or less
0.04 to 0.4	0.015 to 0.16	20 or less
The three smaller sizes in combination should not exceed 50%		
Source: Puckett and Hinton, 1974.		

The maximum size sediment that the salmon can tolerate appears to be a function of two variables. First the maximum sizes that the salmon can physically move during redd construction and second, the size where the eggs are no longer retained but washed out of the interstices between the particles. We could not find any criteria on either of these two variables.

Appendix A shows spawning gravel criteria plotted on gradation curves. The shaded area is the acceptable range of spawning gravel sizes developed from published criteria. The upper part of the curve follows the lognormal distribution of Shirazi et al (1981), the lower portion of the curve uses the maximum acceptable fines as described by Bjornn and Reiser (1991).

Spawning gravel that plots toward the center of the shaded area is the most suitable. Spawning gravel that plots towards the edges are less suitable, and gravel that plots outside the shaded area are not acceptable based on these criteria.

Note that many of the samples plot outside the acceptable range in the coarse area. This is especially true of the surface layer. The subsurface layer is finer and generally meets spawning gravel criteria.

A primary factor affecting spawning gravel quality measurement is whether the sample area has been recently spawned. The salmon alter the composition of the gravel during the spawning process. First, fines are washed away into suspension, removing the finer part of the gradation curve. Second, the coarse material is sorted when the female digs the nest. Coarser gravel and cobbles remain in the nest, or trough, area, and the finer gravel is moved by the current to the tailspill of the redd, or the dune. This difference in

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composition was noted during the sampling, with a significantly coarser deposit in the trough.

A third factor is the depth of spawning. The permeability measurements in the next section clearly define a boundary between spawned and un-spawned gravel. This boundary is typically between 12 and 18 inches below the riffle surface. The boundary is marked by a large and dramatic change in permeability and the amount of fine material.

5.5   RELATIONSHIP BETWEEN SURFACE AND BULK SEDIMENT SAMPLING

Wolman surface sampling is simpler, quicker, and cheaper than bulk sampling. For this reason, it is advantageous to establish a correlation between bulk and surface sampling. Once established, Wolman sampling may be used to estimate the corresponding bulk sample distribution.

Previous studies on the Sacramento River (DWR 1994) and on the Feather (DWR 1982) showed a correspondence that would allow a rough estimate of gravel composition. In general, the surface sample was coarser than the corresponding bulk sample.

In this study, we compared bulk surface sampling with Wolman surface sampling, with mixed results. Figure 5.5-1 shows the 2003 D_{50} data comparison of Wolman surface sampling and surface bulk sampling. In the Low Flow Reach, the linear best fit line of the bulk samples are coarser than the Wolman samples. In the High Flow Reach, the opposite is true. Overall there is a good correspondence. Figure 5.5-2 shows a similar correspondence for the Dg.

Based on the results of the comparison, we conclude that Wolman surface samples may be used to estimate the composition of the armor layer without bulk sampling. Subsurface bulk samples do not correlate well with the Wolman data.

Figure 5.5-1. 2003 Wolman and Bulk Surface Gravel Sample D$_{50}$s Comparison
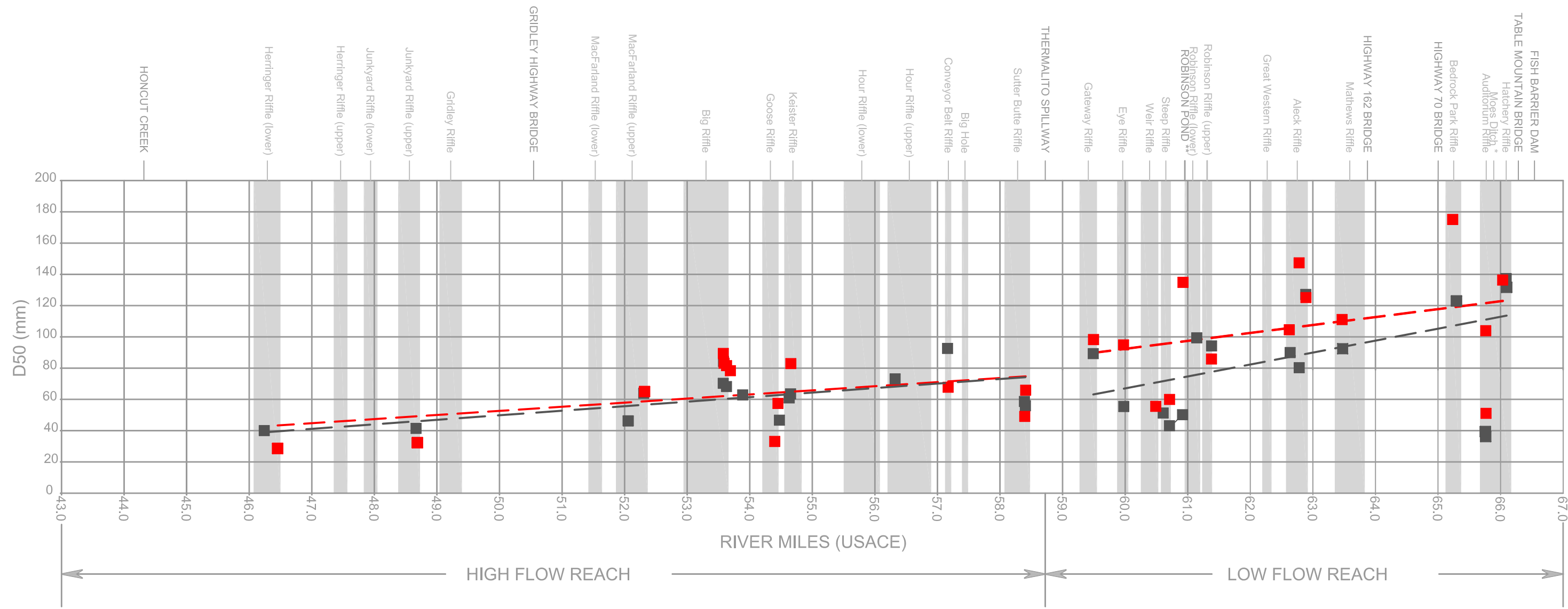
LEGEND

■ 2003 Bulk Sample D50

■ 2003 Wolman Sample D50

— — — — — 2003 Bulk Sample D50 -Linear Best Fit

— — — — — 2003 Wolman Sample D50 - Linear Best Fit

NOTES
1) River miles based on USACE 1997 river center line. 0.0 = Feather River intersection with Sacramento River.
2) D50 - b-axis in millimeters.
3) * Spawning gravel injection at Moe's Ditch from 1971 to 1982, therefore, Linear Best Fits do not include these samples.
4) ** Robinson Pond - apparent gravel trap

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FIGURE 5.5-1
SP-G2 TASK 2
2003 WOLMAN AND BULK
SURFACE GRAVEL SAMPLE
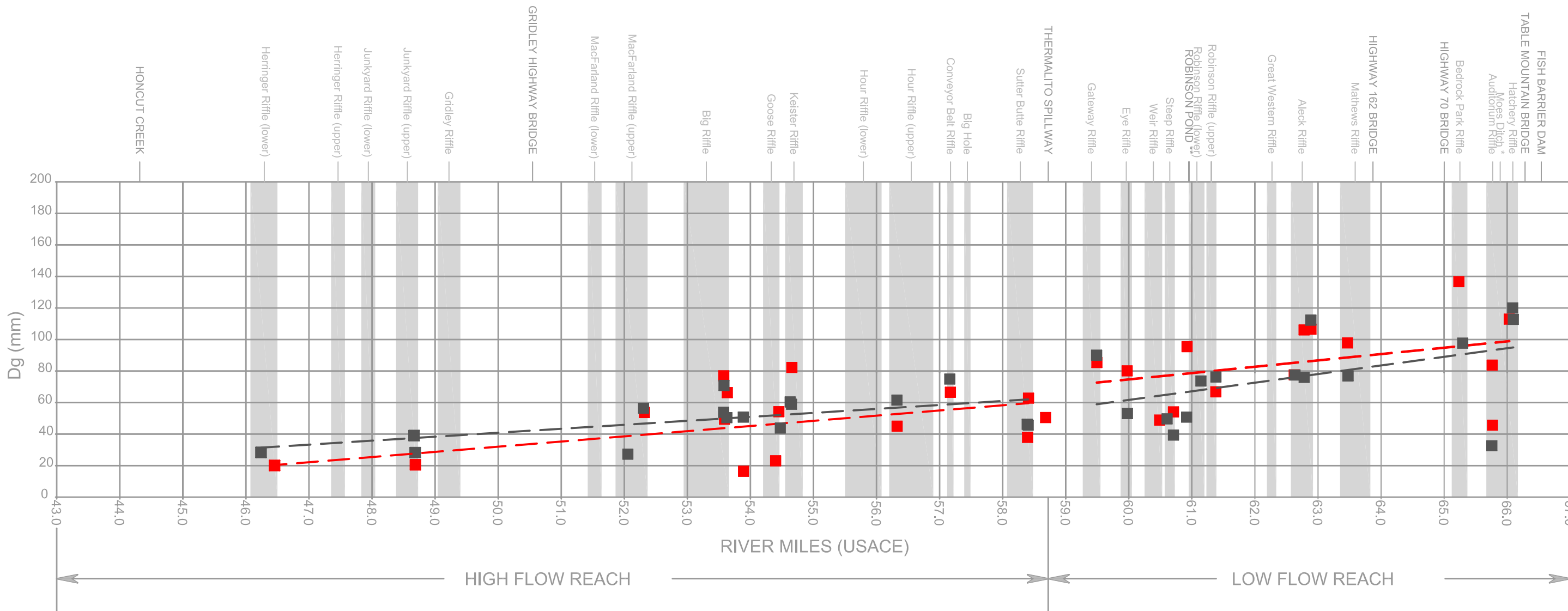D50s COMPARISON

| Prepared by: GMG -- DWR | Date 8/10/ 04 | Filename Figure 5.5-1.dwg |

Figure 5.5-2. 2003 Wolman and Bulk Surface Gravel Sample Dgs Comparison

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FIGURE 5.5-2
SP-G2 TASK 2
2003 WOLMAN AND BULK
SURFACE GRAVEL
SAMPLES Dgs COMPARISON

Dg (mm)

RIVER MILES (USACE)

HIGH FLOW REACH

LOW FLOW REACH

HONCUT CREEK
Herringer Riffle (lower)
Herringer Riffle (upper)
Junkyard Riffle (lower)
Junkyard Riffle (upper)
Gridley Riffle
GRIDLEY HIGHWAY BRIDGE
MacFarland Riffle (lower)
MacFarland Riffle (upper)
Big Riffle
Goose Riffle
Keister Riffle
Hour Riffle (lower)
Hour Riffle (upper)
Conveyor Belt Riffle
Big Hole
Sutter Butte Riffle
THERMALITO SPILLWAY
Gateway Riffle
Eye Riffle
Weir Riffle
Steep Riffle
Robinson Riffle (lower)
ROBINSON POND **
Robinson Riffle (upper)
Great Western Riffle
Aleck Riffle
Mathews Riffle
HIGHWAY 162 BRIDGE
HIGHWAY 70 BRIDGE
Bedrock Park Riffle
Moes Ditch *
Auditorium Riffle
Hatchery Riffle
TABLE MOUNTAIN BRIDGE
FISH BARRIER DAM

LEGEND

■ 2003 Bulk Sample Dg

■ 2003 Wolman Sample Dg

– – – 2003 Bulk Sample Dg - Linear Best Fit

– – – 2003 Wolman Sample Dg - Linear Best Fit

NOTES
1) River miles based on USACE 1997 river center line. 0.0 = Feather
   River intersection with Sacramento River.
2) Dg - b-axis in millimeters.
3) * Spawning gravel injection at Moe's Ditch from 1971 to 1982,
   therfore, Linear Best Fits do not include these samples.
4) ** Robinson Pond - apparent gravel trap

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FIGURE 5.5-2
SP-G2 TASK 2
2003 WOLMAN AND BULK
SURFACE GRAVEL
SAMPLES Dgs COMPARISON

Prepared by:
GMG -- DWR

Date
8/10/ 04

Filename
Figure 5.5-2.dwg

6.0   SPAWNING RIFFLE PERMEABILITY, DISSOLVED OXYGEN, AND TEMPERATURE TESTING

Dissolved Oxygen (DO), Temperature (T) and intragravel water flow are important factors for survival of salmon eggs until emergence. Fourteen riffles between the Feather River Fish Hatchery and the Gridley Bridge on the Feather River were tested. These measurements are made at 6, 12, and 18 inch depths below the gravel surface. With the permeability, measurements made using a modified Terhune (1958) method with an electric pump (McBain and Trush 1994). This method uses a constant drawdown technique and uses the pump to maintain the drawdown within the standpipe. The volume delivered to the standpipe over time is related to the permeability using an empirically derived curve (Horner 2003).

Velocity measurements were also made at each permeability location using a Price meter and a wading rod at the standard .6 depth below water surface when water depth was shallower than two feet or averaging measurements taken at .2 and .8 the depths when greater. Velocities were taken at four inches above the river bottom surface to try to get a representative velocity where the eggs are laid. The river velocities and site locations are included in the data tables.

6.1   SITE SELECTION

Riffles were chosen due to the ease of accessibility (shallower water) and the higher degree of observed spawning at these locations. Active redds were sampled a few feet in front of the egg mass (Figure 6.1-1) at the top, middle and bottom of the selected riffles when possible.

Nine riffles were tested on the Low Flow Reach. Redds at the top, middle and bottom of riffles were measured at Hatchery, Auditorium, Bed Rock Park, Mathews, Robinson and Eye Riffles. Eye and Hatchery Riffles also had permeability tests made in August and September before active spawning occurred at these sites. These data are also presented but should be evaluated separately. Two tests were made at Aleck, Steep, Weir and Gateway Riffles. At Aleck and Steep Riffle, tests were made at the top and mid riffle sections. At Gateway they were made on top and lower riffle. Weir Riffle is actually a glide that turns into a run so one test was made in the glide reach and one in the run.

In the High Flow Reach (from the Afterbay Outflow to the Gridley Bridge, every other major riffle was tested due to time constraints and accessibility. Tests were done at Sutter Butte, Upper Hour, Keister, Goose and MacFarland riffles. Redds at the top middle and lower reaches of the riffles were done on Sutter Butte, Upper Hour, and Keister Riffles. The upper and lower riffle areas were done at MacFarland and only the upper was done at Goose. The skipped tests were due to lack of recently active redds, or deep and/or swift water.
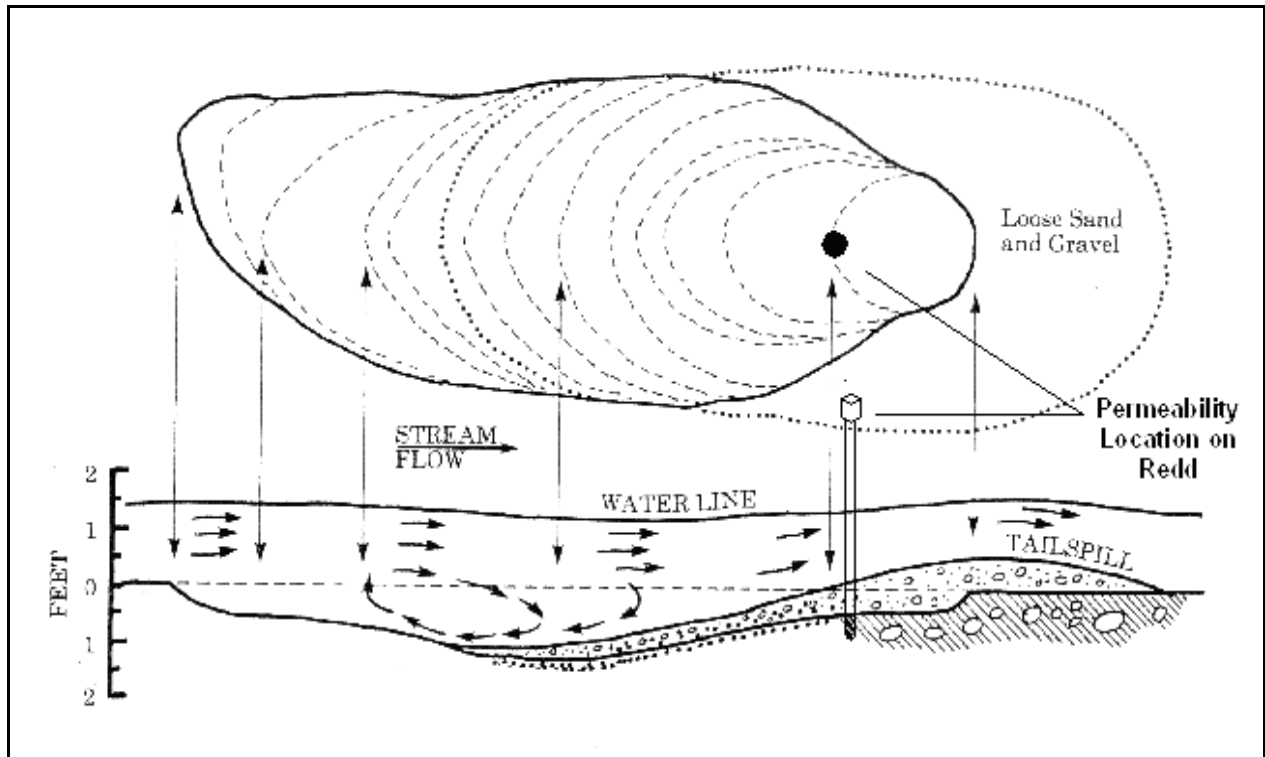
Figure 6.1-1. Ideal Permeability Test Location on Salmon Redd.

6.2   EQUIPMENT

The following equipment was used by DWR-ND to perform permeability, DO and temp testing:

1) <u>Stainless steel standpipe (Figure 6.2-1)</u> - 4.4 foot long and made of 1 $^3/_4$ -inch (outside diameter) stainless steel pipe with a stainless steel driving point on one end and a 2 ½ -inch diameter collar on the other. Approximately between 2 ½ inch to 4 ½-inch above the driving point, the tube is perforated with forty-eight evenly spaced 3.2 mm diameter holes. These holes are placed along 16 vertical 1.6 mm wide by 1mm deep groves in a staggered fashion.
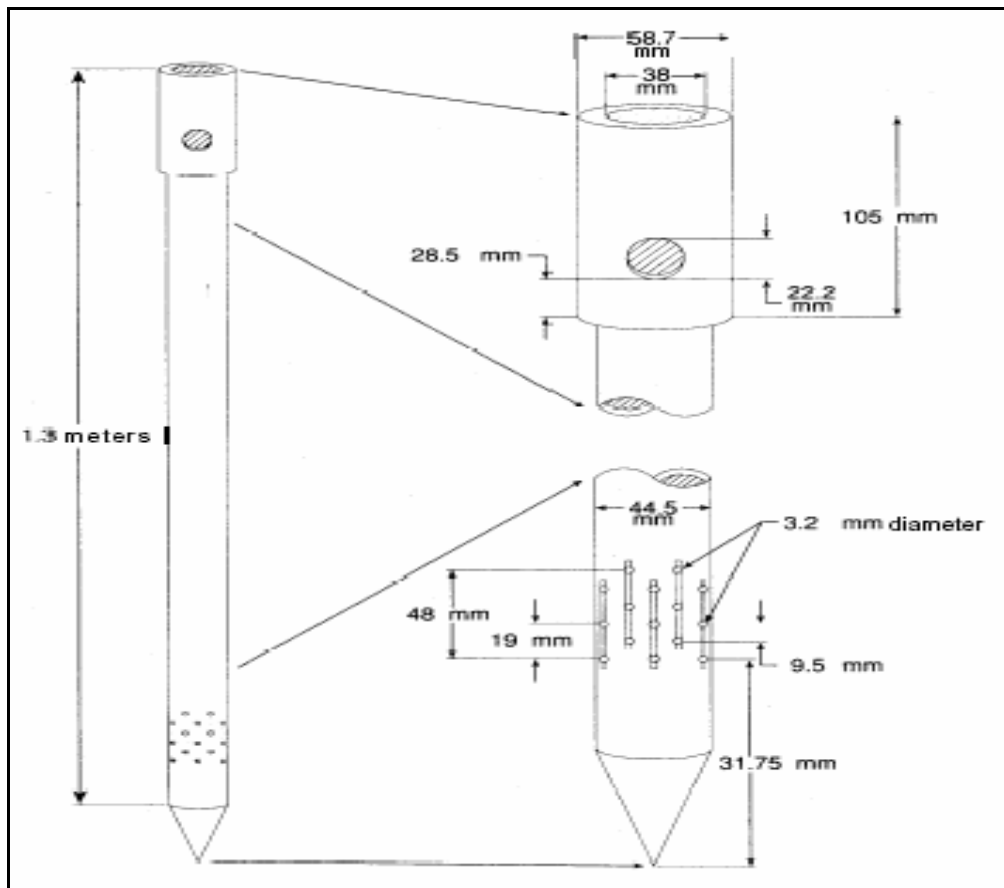
Figure 6.2-1 Modified Terhune Standpipe.
2) <u>Stainless steel driving head</u> - placed on top when driving standpipe into the gravel.

3) <u>Electric diaphragm vacuum pump, Thomas Inc., model 107CDC20</u> - mounted inside a toolbox on a backpack and connected to a universal 12-volt battery. The power supply to the pump is connected to a switch mounted though the side of the instrument.

4) Primary vacuum chamber- A cylinder, 4-inch diameter by 30 inches long and holds 6 liters of water. It is constructed from two pieces of clear plastic glued together with epoxy and capped at the ends. A half inch hole was drilled into the bottom cap and is sealed with and expandable boat plug, which allows the chamber to be drained after each run.

5) WTW Oxi 330i meter- Measures temperature and dissolved oxygen.

6.3   SETUP

The standpipe is driven using a sledgehammer and the driving head to the first selected depth, six inches from gravel surface to midpoint of perforations. This depth is measured from the top of the standpipe to the surface due to difficulty seeing lines drawn on the standpipe under the water.

The test equipment is mounted on a tripod. A 3/8 -inch diameter plastic tubing connects the pump to an overflow bottle. A second 3/8 -inch plastic tube is attached to the side of the vacuum chamber by a brass fitting approximately 3 inches from either end. This tubing acts a piezometer, to facilitate reading the calibrations. A setup is shown in Photo 6.3-1.

Another piece of 3/8- inch plastic tubing attaches to the top of the vacuum chamber and leads to a probe consisting of a 5 foot piece of 3/8 -inch diameter stainless steel tubing. When the pump is turned on, water is drawn into the vacuum chamber via the probe.

Photo 6.3-1. Permeability Test Equipment Setup at Eye Riffle

6.4   TESTING PROCEDURES

The standpipe is purged by running the vacuum probe to the stand pipe bottom and moving it around until the water is relatively clear. When the purging is complete, the water is allowed to stabilize inside the pipe to its pressure potential (this should take only a few seconds in highly permeable gravels to a few minutes in very low permeable materials). Drain the vacuum chamber.

Next, measure the distance from the top of the standpipe to the stream/river surface. This is most easily done by attaching a ½- inch by 2- foot long piece of pipe to the outside of the standpipe ensuring one end is sticking above the water surface. This creates a stilling well that is not being disturbed by the standpipe or researchers legs. Perform a "slurp test", in which the pump is turned on and the probe is slowly lowered into the stilling well until the tip contacts the water and makes a "slurping-straw" sound.

A vise-grip type plier is then clamped to the probe flush to the top collar of the standpipe. The distance from the tip of the probe to the edge of the clamped vise-grip was measured to the closest .01 foot. Repeat the slurp test on the inside of standpipe to get stage height of the intragravel water. This head difference is a measure of the upwelling or downwelling potential at this location (Horner 2003).

Clamp another vise-grip pliers 1-inch above the other and then remove the first. This is done either by measuring or by using a spacer. Lower the probe back into the standpipe with the tip of the probe exactly 1-inch below the elevation of the water surface within the standpipe. This distance is critical, since it was found in one trial that lowering the probe 0.30-inch increased the permeability reading 62 percent. The permeability of the surrounding gravel determines the rate of flow into the standpipe.

Permeability measurements are made by pumping water from the standpipe into the vacuum chamber and measuring the time it takes fill a unit volume (1/2 or 1 liter). Since the vacuum chamber holds six liters, the middle four being calibrated, four or eight measurements can be made per run depending on unit volume being used. The determining factor on deciding the unit volume to use is the time it takes to fill ½ liter; if it takes less than two minutes to fill the first 1/2 liter then 1 liter unit volume will be used. If the time is greater than two minutes, then 1/2 liter unit will be used. A total of eight timed measurements are obtained in either one or two runs. McBain and Trush recommend collecting at least five measurements, and to continuing beyond five measurements until the last one is not the highest permeability. Several researchers have observed a general trend of increasing permeability during the first several replicates, noted by the decrease in time required to fill the same volume of the chamber (McBain and Trush 2000). We did not noticed this as an overwhelming trend, most likely from the purging before the initial run, thus our eight timed measurements should more than satisfy this rule.

After the last run is completed, dissolved oxygen (DO) and temperature readings are taken inside the standpipe. This is done by lowering meter probe into the standpipe to a depth adjacent to the perforations and moving up and down a few inches until the reading stabilizes. This can take anywhere from a minute to 10 minutes depending on the meter. Next, a DO and temperature measurement is made in the river and recorded. A WTW Oxi 330i meter was used on all tests.

The driving head is then placed back onto the standpipe and driven to the next selected depth of 12 inches. The procedure will then be repeated at this depth and then at 18 inches.

6.5   RESULTS

The results are discussed in three separate sections on permeability, dissolved oxygen, and temperature. In the Fall of 1968 the Department of Fish and Game used standpipes designed like those used by Gangmark and Bakkala (1958) at Hatchery, Hour Goose and Herringer Riffles to measure intragravel water velocities, dissolved oxygen and water temperatures (Painter and Wixom 1977). The results from these measurement along with surface water dissolved oxygen and temperature measurement are included in Table 6.5-1.

Table 6.5-1. Fall 1968 Mean Intragravel DO Concentration, Water Temperature, and Seepage Velocity along with Surface Water DO Concentration and Temperature.

Riffle	Date	Number of standpipes sampled	Mean intergravel oxygen (ppm)	Surface water oxygen (ppm)	Mean intergravel temp.(c)	Surface water temp. (c)	Mean seepage velocity (cm/hr)
Hatchery	10/4/1968	10	10.8	11.15	12.5	12.4	96
Hour	1-Oct	3	8.7	9.3	18.7	18.9	50
	2-Oct	6	9	8.9	17.8	17.8	80
	17-Oct	9	10.1	9.6	14.7	15.4	89
	25-Nov	8	11.2	10.9	11.7	11.4	100
Goose	7-Oct	4	8.7	10	17.4	17.3	101
	9-Oct	9	10.4	10.3	16.2	15.7	71
	18-Oct	9	11.5	10.1	15.6	14.8	84
	19-Nov	19	9.4	11.1	12	11.9	47
Herringer	11-Sep	6	8.3	9.6	22.1	22	45
	13-Sep	3	8.7	9.2	21	21	29
	16-Oct	4	9.6	10.3	14.8	14.7	63
	19-Oct	2	9.3	10.2	15.5	15.4	79
	20-Oct	3	7.7	9.9	15.1	15.2	
	22-Nov	9	8.4	11	11.7	11.4	

Modified from Painter and Wixom 1977

6.5.1 Permeability

Permeability is a measure of the capacity of a substance to transmit a fluid. Permeability was calculated for lower Feather River spawning gravels using two methodologies. The direct approach was to use a permeameter in the field to pump test spawning gravels at different depths. The indirect approach was to use gravel sampling data to infer permeability. The two methodologies were compared.

The permeability and the intragravel water velocity are related. The velocity may be described as the volume of water per unit time passing a cross sectional area containing both solids and interstitial openings along a line in the direction of flow from one point to another (Vyverberg et al. 1997; McBain and Trush 2000). This velocity can be calculated using the permeability and the local hydraulic gradient through the following equation:

$$V = k\Delta h/L,$$

where k is the permeability and ($\Delta h/L$) is local hydraulic gradient. In this equation, the hydraulic gradient is dimensionless ($\Delta h/L$ = length/length), thus permeability will have the same units as the intragravel velocity (cm/hour). Tehune in 1958 suggested that permeability be used as a substitute for velocity as an empirical measurement for spawning gravels (McBain and Trush 2000). Our study adopted this methodology.

Permeability and intragravel flow is essential for transportation of oxygen to metabolic waste from incubating egg surfaces (Allen and Hassler 1986). Survival of Chinook salmonid eggs is related to intragravel water velocities (Vyverberg et al. 1997). In a study of Chinook salmonid emergence on Mill Creek, a tributary of the Sacramento River, it was found that the mortality rate of eggs was related to intragravel velocities, as shown in Table 6.5-2 (Gangmark and Bakkala 1960).

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Table 6.5-2 Chinook salmon mortality of embryos in relation to Intragravel water velocity.

Intragravel Water Velocity	Average Embryo Mortalities
cm/hr	Percent
<15.24	>40
15.24-<30.48	33.1
30.48-<45.72	24
45.72 -<60.96	10.1
60.96-<76.20	12.9
76.20-<91.44	13
91.44-<106.68	10.8
106.68-<121.92	5.3
121.92-<137.16	2.9
137.16-<152.40	3.8
>152.40	5.8

From Gangmark and Bakkala (1960).

The method used to measure permeability involved actual measurement of flow. The study focused on the permeability of recently spawned salmon redds, as described in the previous section.

Before spawning had commenced in Fall 2003, a small pilot study was run to test the equipment and methodology at different geomorphic locations on a riffle. Twelve tests were done on the upper and middle reach of Eye Riffle and two tests at the lower reach of Hatchery Riffle. These tests showed wide variability in permeability at both location and at different depths. Some of the test locations were probably last year's spawning redds, while others were undisturbed bed material. The data also shows large decreases in permeabilities at depths from 12 to 18 inches. These measurements were probably below the redd excavation zone, and instead measured the permeability of the river bottom.

The depth of burial may vary considerably in salmon redds. On the Trinity River, the depth to bottom of egg pocket from the river bed ranged from 4 -inch (10.5 cm) to 20-inch (51 cm) with a mean of 12 -inch (30.0cm) (Evenson 2001).

The depth of egg burial is of primary concern when evaluating this permeability data. The depths of our tests were at 6, 12 and 18 inches so if the redd that was tested was shallower than 12 inches the permeability for the bottom two depths would be actually a permeability for the channel bottom rather than the redd.

Permeability testing results are shown in Table 6.5-3. The table shows that at the 6 inch depth, the permeability readings ranged over an order of magnitude, ranging

from 4,700 to 40,300 cm/h with an average 24,900 cm/hr. This is considerably higher than the reading gotten in the pilot study on non-redd locations where the permeability results had ranged from 500 to 5,600 cm/hr (2,300 cm/hr average). At 12 inches, the permeability ranged from 500 to 38,900 cm/hr and at 18 inches from 100 to 22,400 cm/hr. It is likely at these depths some of our readings were beneath the egg pocket depth.

MaBain and Trush (2000) calculated embryo survival based on permeabilities using a relationship developed by Tagart (1976) and McCuddin (1977). This is shown in Figure 6.5-1. McCuddin's research dealt with chinook salmon and Tagart with coho. Even though there work dealt with different species, survivability of embryos correlated well with permeability.

Table 6.5-3. Permeability results at Chinook salmon redds (October – November 2003).

Reach	Riffle	Location on Riffle	Site Code	PERMEABILITY (cm/hr)		
				6 inch	12 inch	18 inch
Feather River Low	Hatchery	Top	PT-HR-C	27,300	600	300
		Middle	PT-HR-D	38,800	5,900	600
		Bottom	PT-HR-E	7,500	700	1,100
	Auditorium	Top	PT-AuR-A	8,700	9,500	10,500
		Top	PT-AuR-D	32,000	1,500	200
		Middle	PT-AuR-B	13,600	14,100	4,000
		Bottom	PT-AuR-C	31,900	8,600	4,100
	Bedrock Park	Top	PT-BR-A	25,700	6,400	1,100
		Middle	PT-BR-B	31,700	700	300
		Bottom	PT-BR-C	6,600	500	400
	Mathews	Top	PT-MR-A	30,200	33,700	2,300
		Middle	PT-MR-B	29,000	1,600	600
		Bottom	PT-MR-C	16,000	3,000	1,200
	Aleck	Top	PT-AIR-A	12,300	1,800	4,700
		Middle	PT-AIR-B	15,600	30,200	9,300
	Robinson	Top	PT-RR-A	40,300	20,100	1,000
		Middle	PT-RR-B	28,700	37,700	5,800
		Bottom	PT-RR-C	4,700	1,400	2,600
	Steep	Top	PT-SR-A	33,900	33,800	3,400
		Middle	PT-SR-B	32,600	34,500	1,200
	Weir	Top	PT-WR-A	37,200	4,500	2,100
		Middle	PT-WR-B	38,500	27,700	1,400
	Eye	Top	PT-ER-M	36,900	32,600	1,500
		Middle	PT-ER-N	22,400	2,800	3,800
		Bottom	PT-ER-O	36,700	18,600	3,200
	Gateway	Top	PT-GR-A	37,000	36,800	11,200
		Bottom	PT-GR-B	11,000	38,900	4,600

Reach	Riffle	Location on Riffle	Site Code	PERMEABILITY (cm/hr)		
				6 inch	12 inch	18 inch
Feather River High Flow	Sutter Butte	Top	PT-SBR-A	9,800	10,000	3,300
		Middle	PT-SBR-B	34,900	4,600	2,400
		Bottom	PT-SBR-C	37,200	15,800	1,800
	Upper Hour	Top	PT-UHR-A	9,900	26,500	13,300
		Middle	PT-UHR-B	11,700	12,500	400
		Bottom	PT-UHR-C	38,300	31,800	500
	Keister	Top	PT-KR-A	32,500	6,700	5,000
		Middle	PT-KR-B	32,400	2,100	1,700
		Bottom	PT-KR-C	10,200	2,000	100
	Goose	Top	PT-GoR-A	21,900	35,300	1,300
	MacFarland	Top	PT-McR-A	17,900	3,000	1,300
		Bottom	PT-McR-B	26,300	35,000	22,400

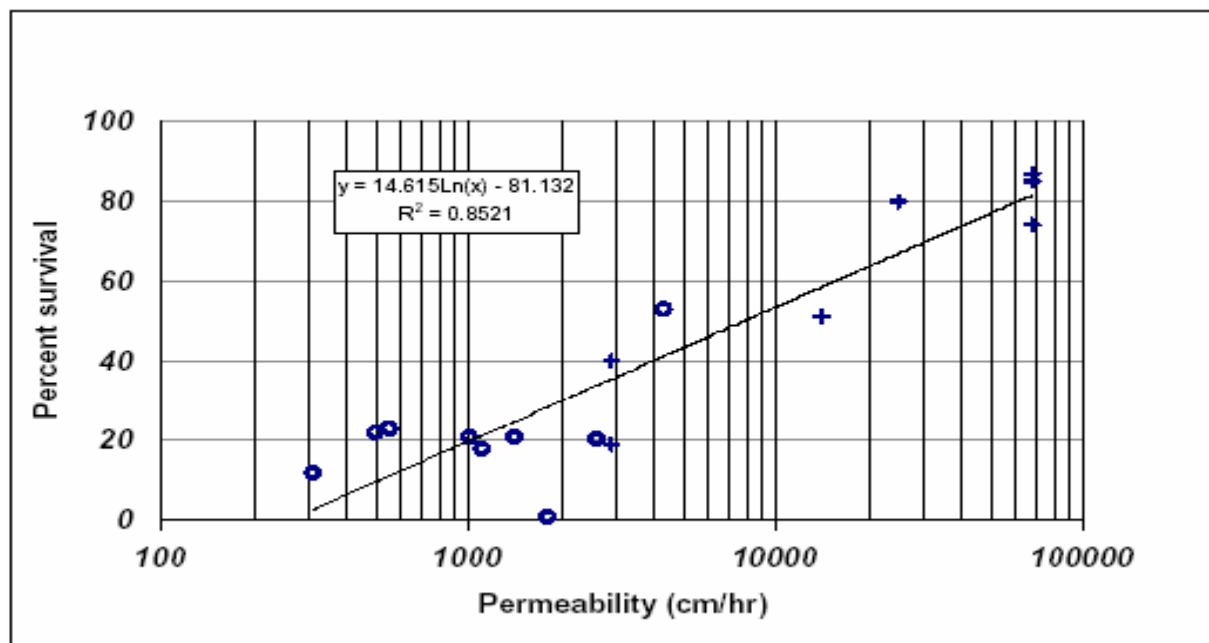*Shaded areas indicate likely disturbed gravels within redd*

Figure 6.5-1 Data from Tagart (1976) and McCuddin (1977) showing a significant relationship between survival of Chinook (McCuddin data, +) and coho salmon (Tagart data, o), and permeability of the incubation substrate.

Using this relationship and comparing with the results that were obtained at the 6 inch depth it predicts embryo survival of 42% (4,700 cm/hr) to 74% (40,300 cm/hr) within

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redds. At the 12 and 18 inch depths results are less clear due to the possibility that the tests were done below the egg pockets beneath the disturbed gravel of the redd. Another limitation of using this comparison is that permeability by itself does not tell you the velocity through the gravel without the gradient.

6.5.2 Dissolved Oxygen

Dissolved oxygen (DO) requirements for Chinook salmon embryos are somewhat unclear. Various studies have indicate minimum levels of DO (with temperature) for egg survival and emergence generally fall between 2 an 8 mg/l (Kondolf 2000; Gangmark and Bakkala 1960; Alderdice et al. 1958; Coble 1961; Shumway et al. 1964; Silver et al. 1965; Davis 1975; Chevalier et al. 1984).

In this study DO readings at the 6 inch depth ranged from 9.4 to 12.1 mg/l (averaging 10.7 mg/l), from 4.2 to 11.9 mg/l (averaging 10.2 mg/l) at 12 inch, and from 0.9 to 11.6 mg/l (averaging 9.7 mg/l) at 18 inch below surface. The lowest reading 4.2 mg/l at 12 inch and 0.9 mg/l occurred at the same permeability test location, PT-BR-C, at the bottom of Bed Rock Park Riffle. Low readings were also observed at the lower end of Mathews Riffle at the 12 and 18 inch depths (6.7 and 5.6 mg/l respectively) and at the upper end of Weir Riffle (actually a glide that turns into a run) at 18 inch depth of 5.6 mg/l. Moderately low readings occurred at the 18 inch depth at the lower reaches of Hatchery and Auditorium Riffles of 7.7 and 7.0 mg/l respectively. These redds are quite possibly beneath the egg pocket depth. At all other sites, the DO reading was above 8.0 mg/l. and usually the reading at the 6 inch depth was within1 mg/l of river at the same time.

A test was conducted for diurnal DO changes within the gravel. At Auditorium Riffle, a stainless steel standpipe was driven into a redd to the depth of seven inches and then monitored from before dawn to dusk. Before each reading, four to five liters were pumped to draw fresh intragravel water into the standpipe. Prior to each reading, DO and temperature were also measured in the river in case the DO meter had a slightly different calibration or had drifted. Table 6.5-4 has the results.

Table 6.5-4. Results of Diurnal Testing for Dissolved Oxygen and Temperature.

Time	River		Redd (6-8 inch)	
	Temp °C	DO mg/l	Temp °C	DO mg/l
5:35 AM	11.4	10.47		
5:40 AM			11.4	10.48
7:15 AM	11.4	11.41		
7:20 AM			11.4	10.99
11:40 AM	11.9	12.37		
11:43 AM			12.1	11.99
2:25 PM	11.9	11.71		
2:28 PM			12.0	11.39
5:20 PM	11.7	10.17		
5:23 PM			11.7	10.57

6.5.3 Temperature

The lower and upper threshold temperature limit for normal development of Chinook salmon eggs was established to be between 40°F and 42.5°F (4.44°C and 5.83°C) on the lower end and between 55°F to 57.5°F (12.78°C to 14.17°C) on the upper end (Combs 1965). Data sheets for the temperature, DO, and permeability are in Appendix A.

Surface water temperature varied from 51.3 to 54.9°F (10.7 to 12.7 °C) in the Low Flow Reach and from 52.7 to 54.5°F (11.5 to 12.5 °C) in the High Flow Reach, as shown in Table 6.5-5. Intragravel water temperatures varied from 51 to 54.9°F (10.5 to 12.7°C) in the low flow reach and from 52.7 to 55.6°F (11.5 to 13.1 °C). At some locations, a difference was found at deeper sample depths, but overall, the average temperatures of the river equaled that of the intragravel water.

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Table 6.5-5. Dissolved Oxygen and Temperature Results in Chinook Salmon Redds

Reach	Riffle	Location on Riffle	Temperature °C				Dissolved Oxygen (mg/l)			
			River	6"	12"	18"	River	6"	12"	18"
Feather River Low	Hatchery	Top	10.7	10.7	10.7	10.7	11.2	10.7	10.1	9.0
		Middle	11.9	11.9	11.9	11.8	10.7	10.6	10.7	10.2
		Bottom	12.0	12.0	12.0	11.9	11.0	10.9	8.9	7.7
	Auditorium	Top	11.5	11.5	11.6	11.6	12.0	11.4	11.9	11.6
		Top	11.8	11.9	11.8	11.7	10.4	10.1	10.3	11.7
		Middle	11.8	11.8	11.8	11.9	11.9	12.1	11.7	11.3
		Bottom	12.0	12.0	11.9	11.6	10.7	11.2	9.6	7.0
	Bed Rock Park	Top	11.2	11.0	11.1	11.2	10.3	10.3	10.4	9.6
		Middle	11.9	11.6	11.9	11.7	10.9	10.6	9.5	10.1
		Bottom	12.1	12.1	11.9	11.8	10.5	11.3	4.2	0.9
	Mathews	Top	10.8	10.8	10.8	10.8	9.9	10.1	10.0	9.7
		Middle	12.3	12.0	12.2	12.3	9.7	9.5	9.9	9.4
		Bottom	12.7	12.6	12.7	12.7	10.6	10.4	6.7	5.6
	Aleck	Top	12.1	11.9	12.0	12.1	11.2	11.3	11.7	11.8
		Middle	12.3	12.2	12.3	12.3	12.2	11.6	12.0	9.2
	Robinson	Top	11.3	11.2	11.3	11.3	9.7	9.7	9.4	9.7
		Middle	10.7	10.7	10.8	10.8	12.3	10.8	10.5	10.8
		Bottom	11.6	11.5	11.6	11.6	11.4	11.0	10.9	10.7
	Steep	Top	11.2	11.2	11.2	11.2	11.0	10.4	10.8	11.0
		Middle	11.4	11.4	11.3	11.3	10.5	10.7	10.0	9.7
	Weir	Top	11.0	11.1	11.2	11.2	10.1	9.5	8.2	5.1
		Middle	11.0	11.0	11.1	11.2	10.3	10.1	10.4	9.4
	Eye	Top	12.3	12.3	12.3	12.3	11.0	10.9	10.8	10.7
		Middle	12.5	12.5	12.4	12.4	11.3	11.2	10.8	10.4
		Bottom	12.6	12.6	12.6	12.6	11.6	11.6	11.4	11.1
	Gateway	Top	11.6	11.6	11.6	11.6	9.8	9.6	9.6	9.7
		Bottom	11.9	11.8	11.9	12.0	10.1	9.4	10.5	8.8

(Samples collected October – November 2003).

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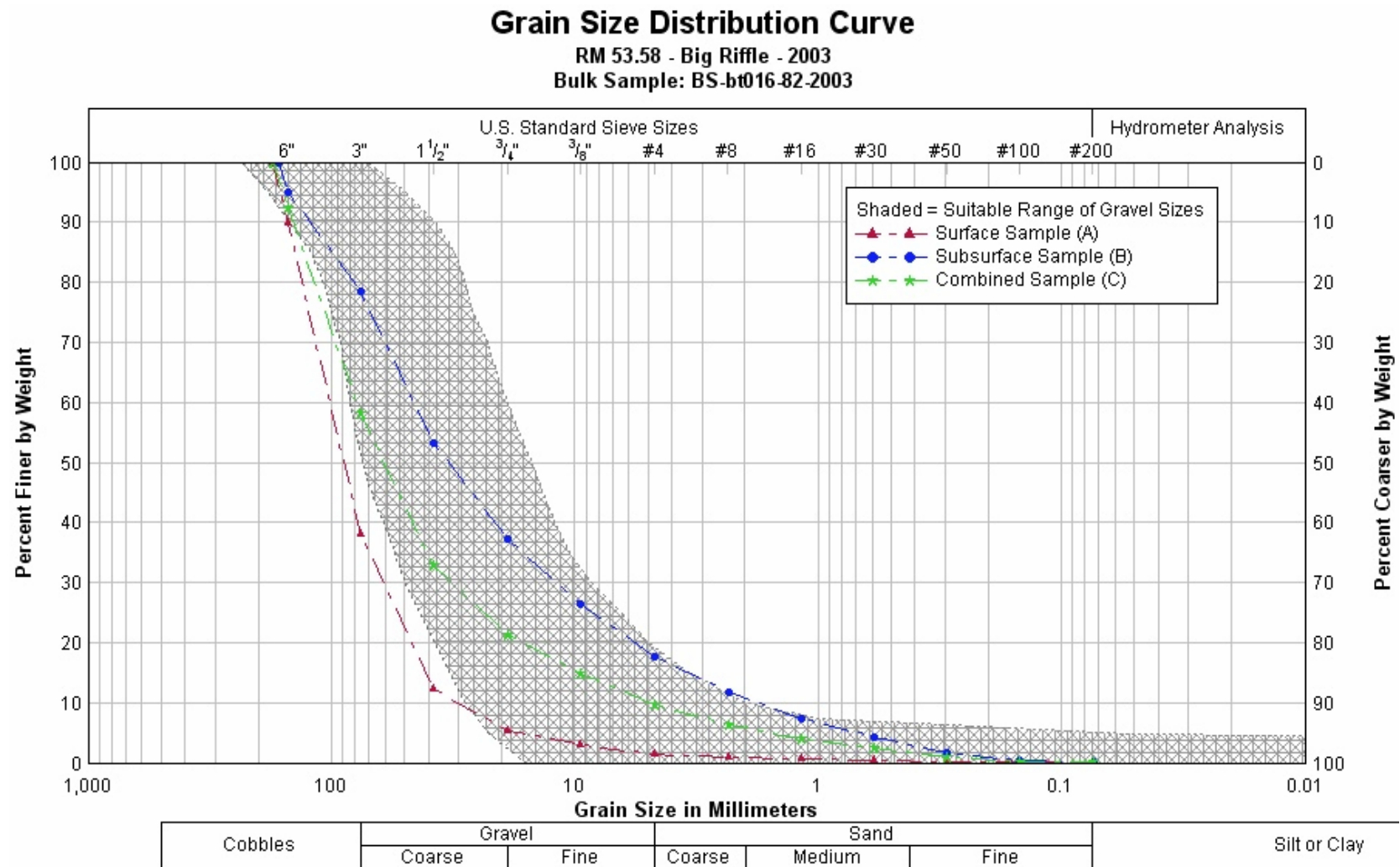
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APPENDIX A: Test Data Sheets

A.1   Graphs of Bulk Sample Data Sieve Analyses
A.2   Tables of Temperature, Permeability and Dissolved Oxygen Analyses

APPENDIX A.1

Grain Size Distribution Curve
RM 53.58 - Big Riffle - 2003
Bulk Sample: BS-bt016-82-2003

Preliminary Information – Subject to Revision – For Collaborative Process Purposes Only

A-3

Oroville Facilities Relicensing Team   August 20, 2004 7:01 PM
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Grain Size Distribution Curve
RM 53.59 - Big Riffle -2003
Bulk Sample: BS-bt017-82-2003

Oroville Facilities Relicensing Team   August 20, 2004 7:01 PM
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Grain Size Distribution Curve
RM 53.63 - Big Riffle (dune trough, combined) - 2003
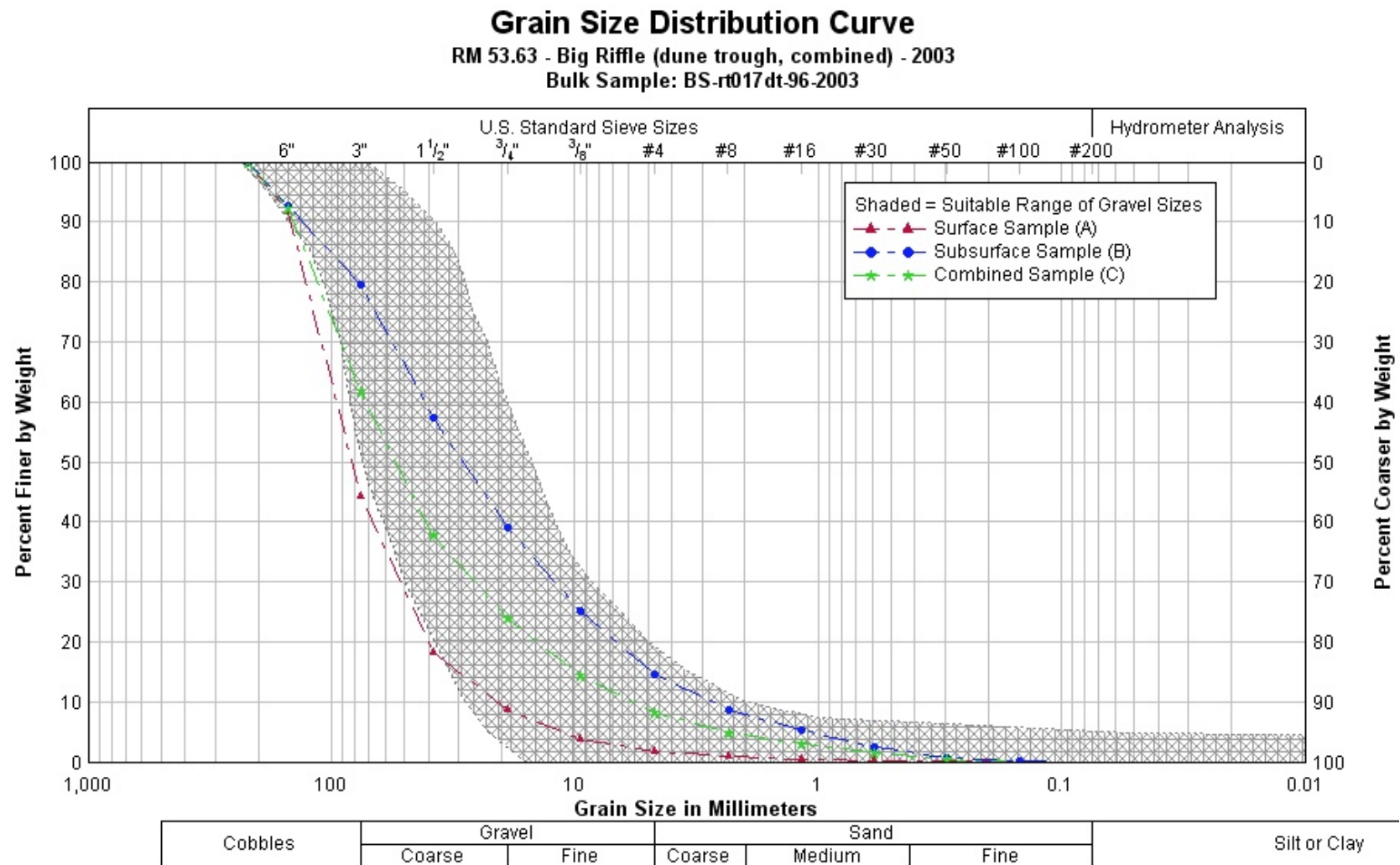Bulk Sample: BS-rt017dt-96-2003

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A-5

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Grain Size Distribution Curve
RM 57.17 - Conveyor Belt Riffle (dune and trough) - 2003
Bulk Sample: BS-rm012dt-82-2003

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Grain Size Distribution Curve
RM-53.79 - Goose Backwater - 2003
Bulk Sample BS-TP- bm004dt-xx-2003

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A-7

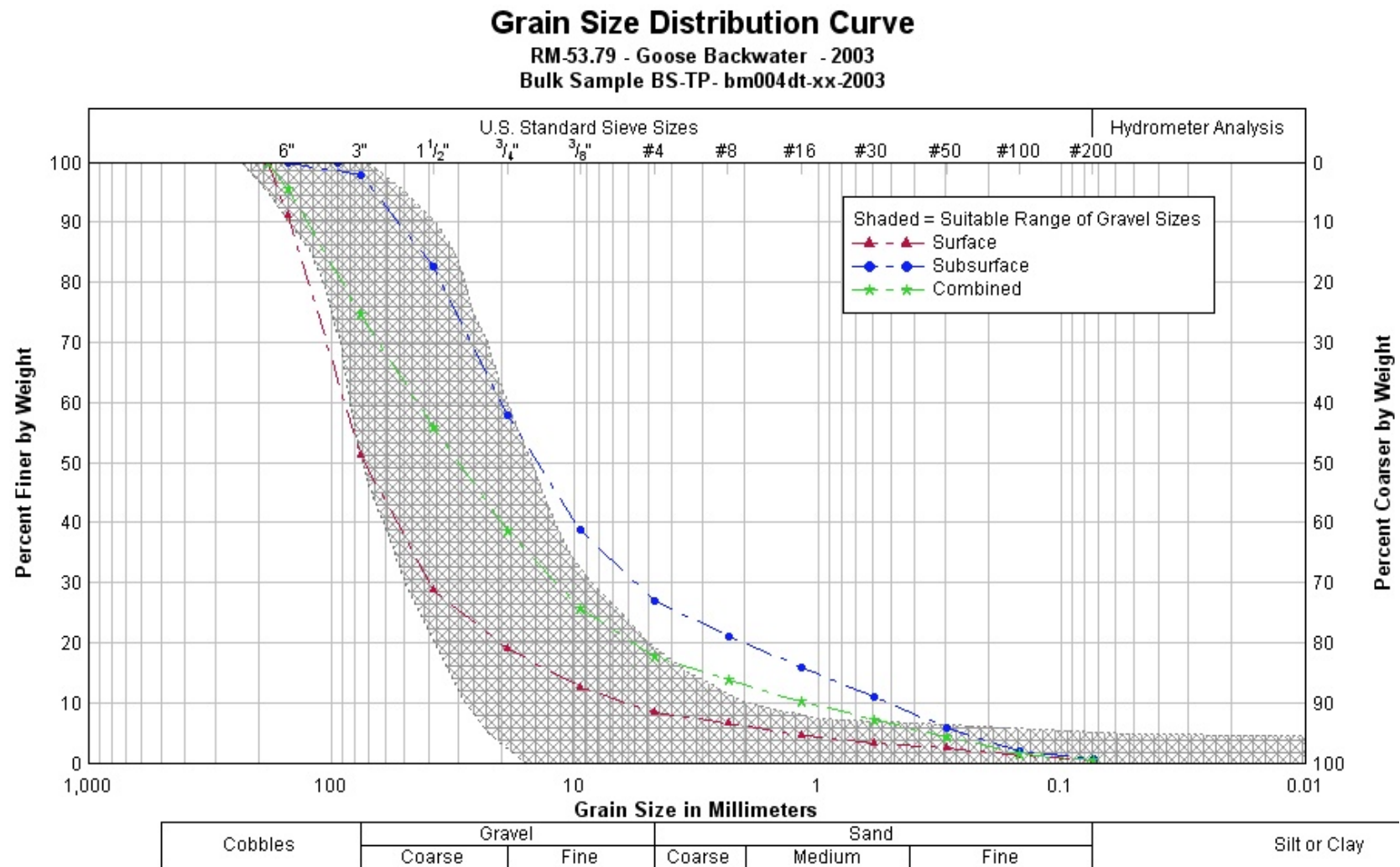Oroville Facilities Relicensing Team   August 20, 2004 7:01 PM
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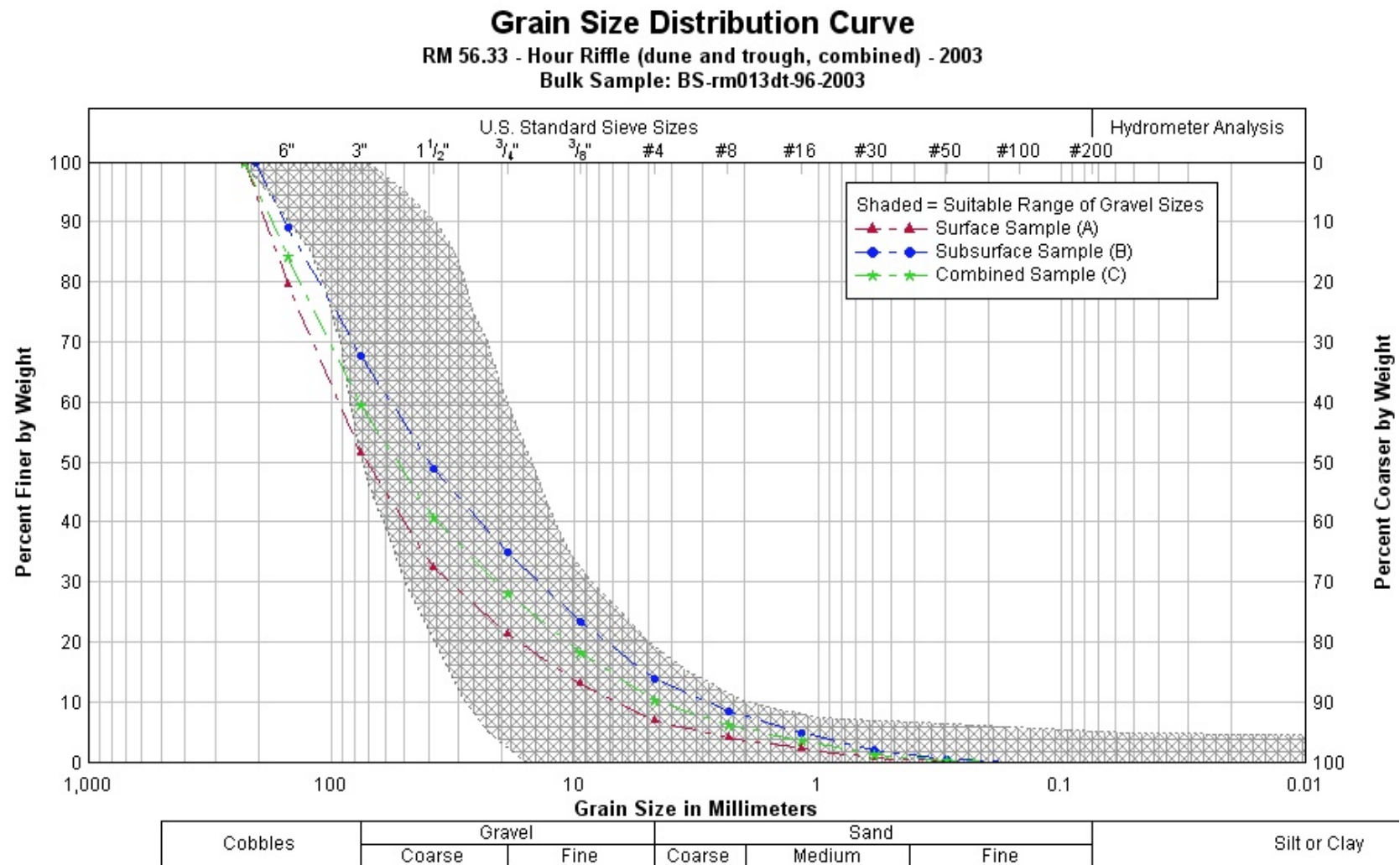## Grain Size Distribution Curve
RM 54.40 - Goose Riffle - 2003
Bulk Sample: BS-rt015-82-2003

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A-8

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Grain Size Distribution Curve
RM 46.45 - Herringer Riffle - 2003
Bulk Sample: BS-bb022/023-xx-2003
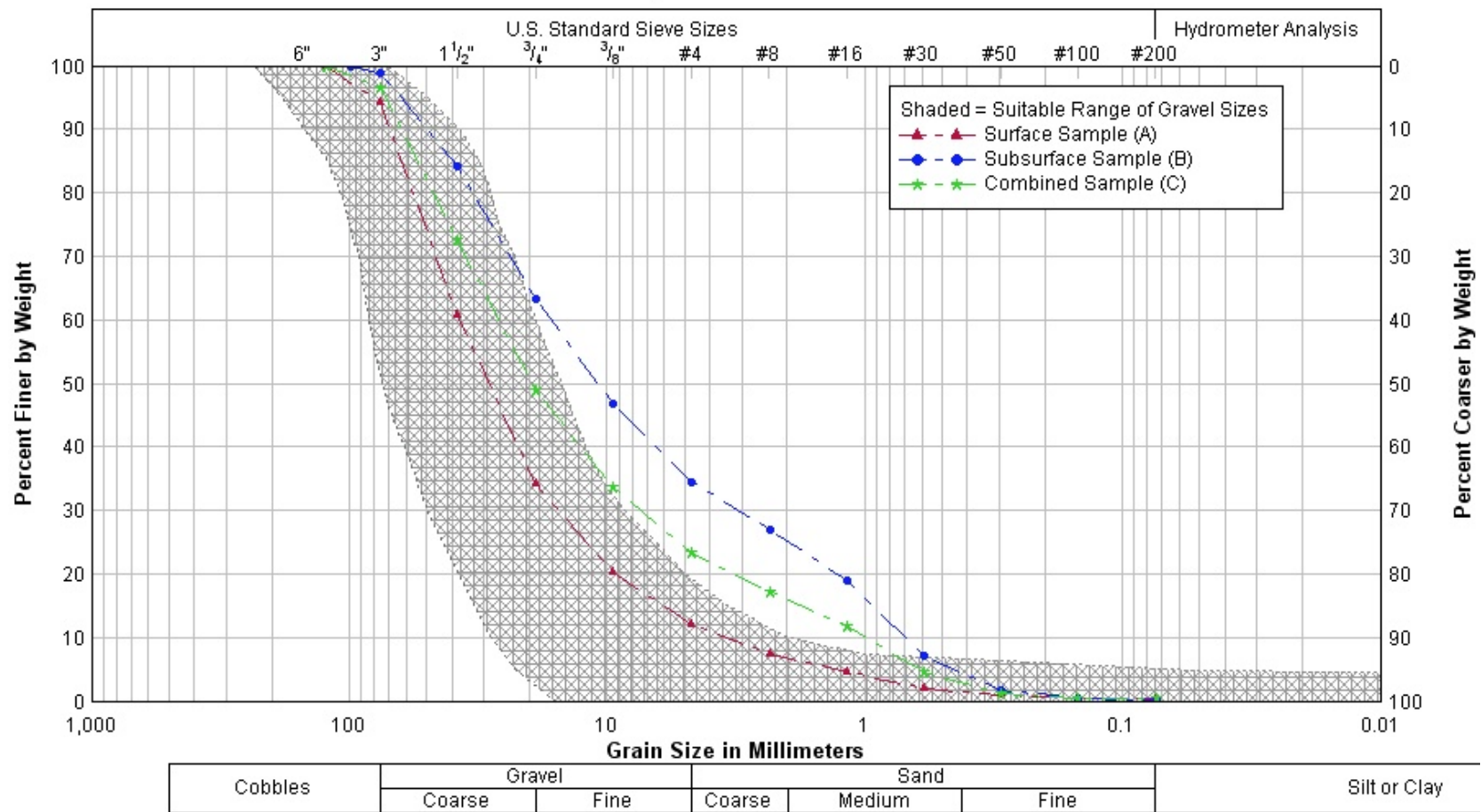
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Grain Size Distribution Curve
RM 56.33 - Hour Riffle (dune and trough, combined) - 2003
Bulk Sample: BS-rm013dt-96-2003

Preliminary Information – Subject to Revision – For Collaborative Process Purposes Only

A-10

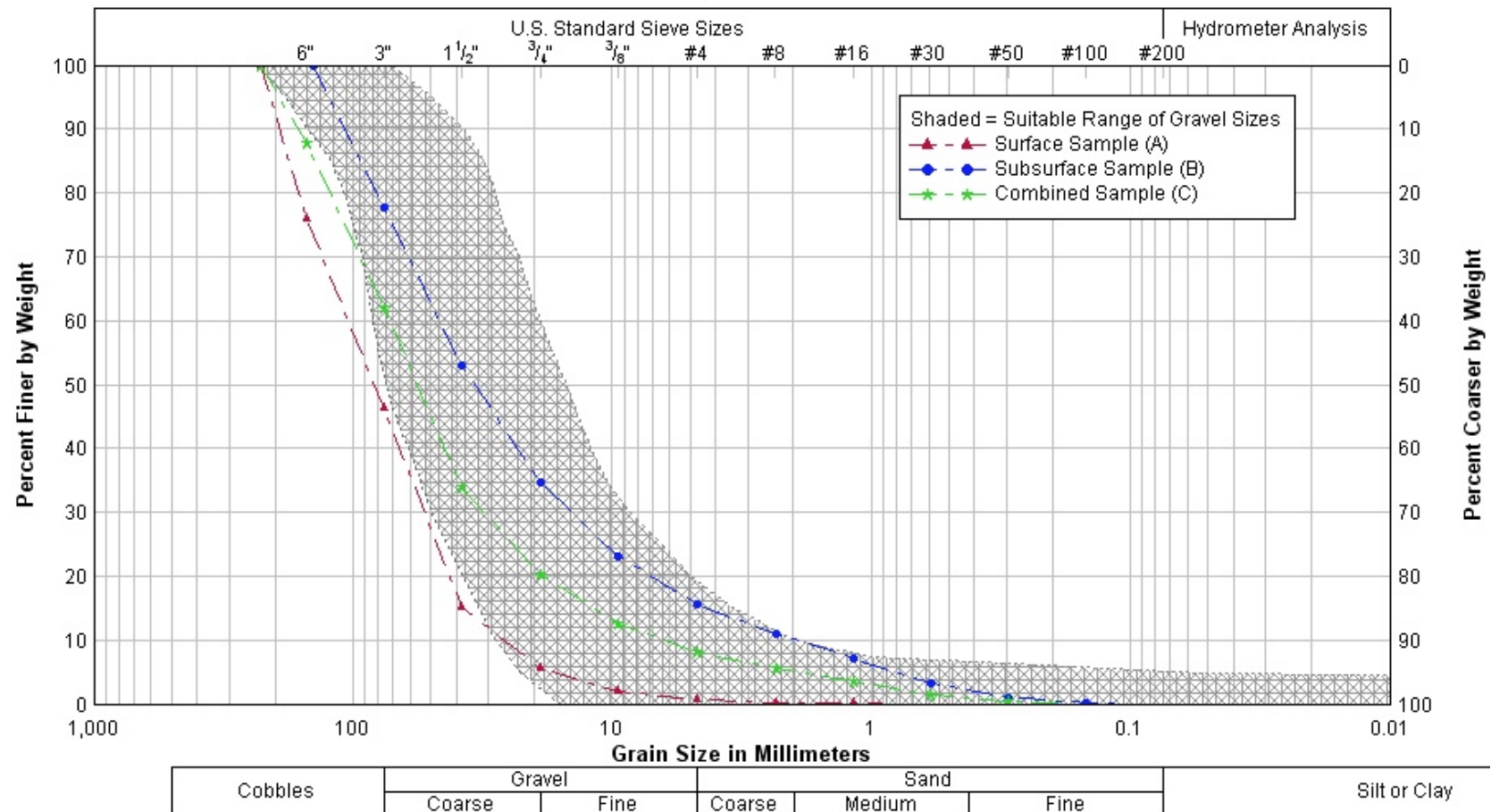Oroville Facilities Relicensing Team   August 20, 2004 7:01 PM
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Grain Size Distribution Curve

RM 48.69 - Junkyard Riffle (dune and trough, combined) - 2003
Bulk Sample: BS-rt020dt-96-2003
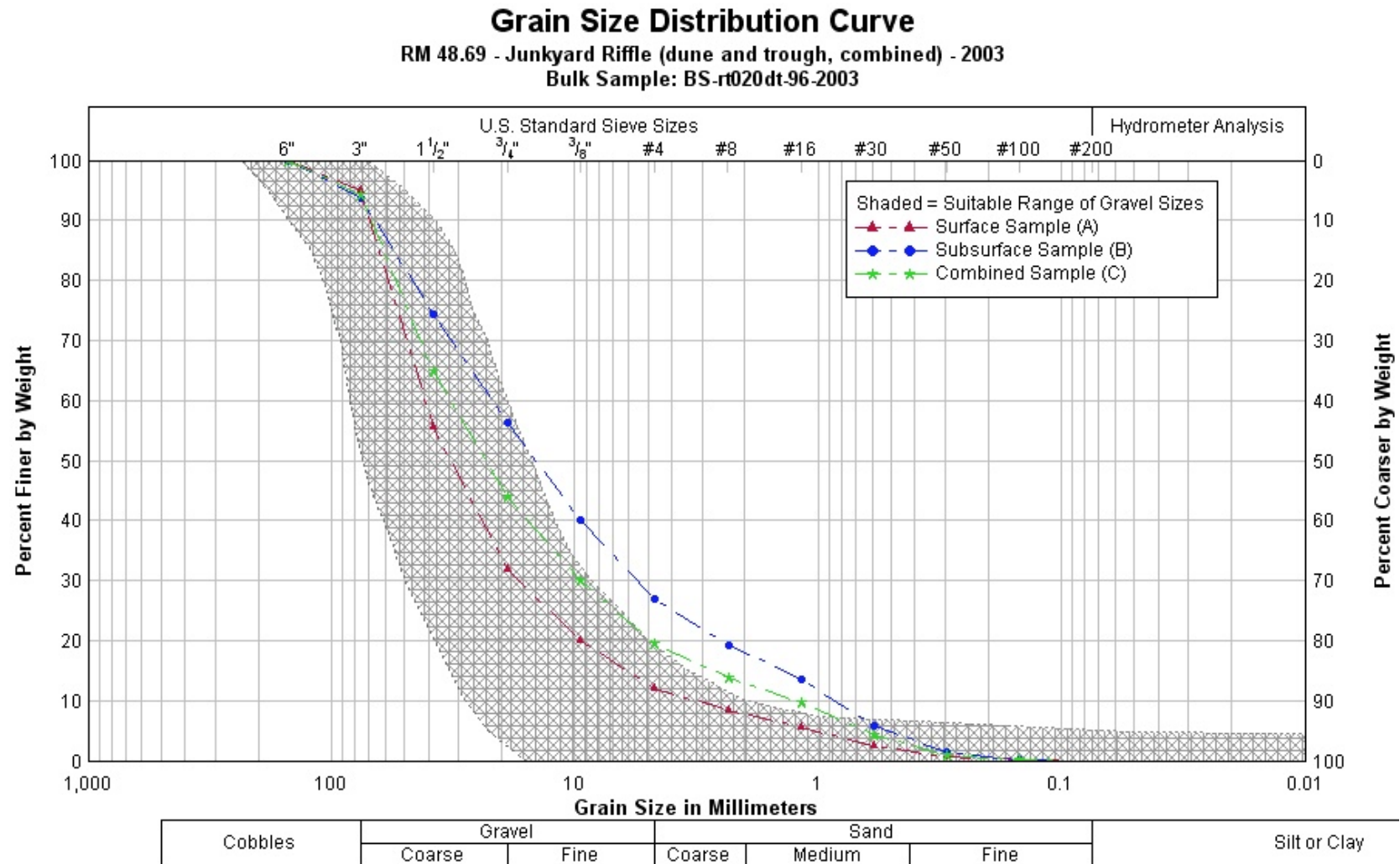
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Grain Size Distribution Curve
RM 54.66 - Keister Riffle - 2003
Bulk Sample: BS-rt014-82-2003

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